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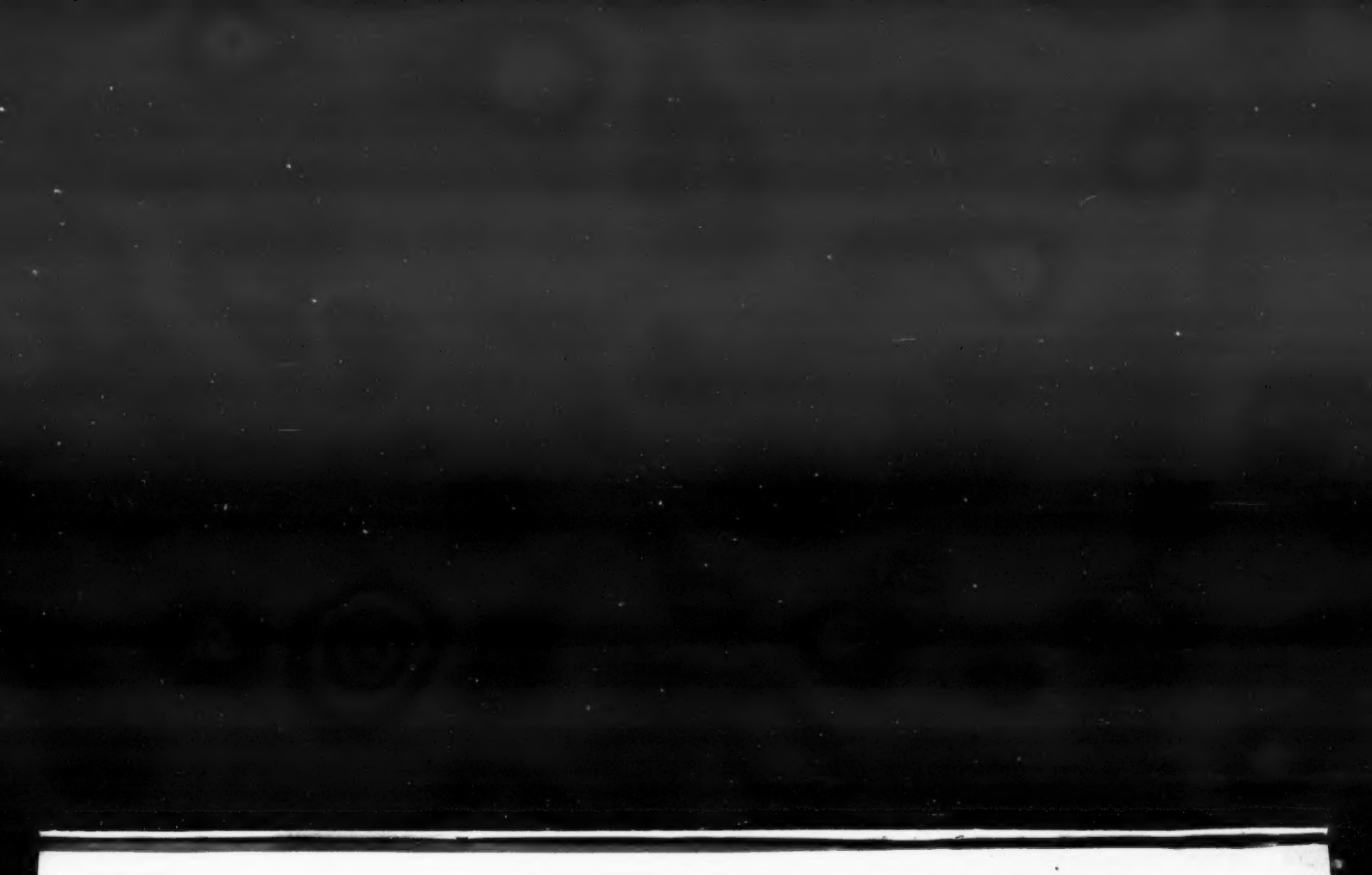


THE

AMERICAN JOURNAL OF SCIENCE

[THIRD SERIES.]

ART. XVI.—*The Appalachian Type of Folding in the White Mountain Range of Inyo County, California;* by CHARLES D. WALCOTT.

[Read before Geol. Soc. America, Baltimore meeting, Dec. 27, 1894.]

THAT portion of the White Mountain range of California, to the structure of which I wish to call attention, is situated between the road passing from Big Pine, Inyo County, in Owen's valley, through Waucobi Canyon to Saline valley, and the crest of the ridge a little south of White Mountain peak. The length of this portion of the range is about forty miles. South of the Saline valley road the range has received the name of Inyo range, and is so named in all reports upon it. Each observer, however, states that he does not see any reason for applying the two names to the range, as the Inyo portion is the southern prolongation of the White Mountain range. On the latest map* published of this region the entire range from Owen's Lake to the California–Nevada line, is called the White Mountain range.

Prof. J. D. Whitney† makes reference to the Inyo and White Mountain ranges, stating that little is known of their geology, except that, from Bend City for twenty-five miles north, their western base and slopes seem to be composed of slates and other stratified rocks, generally dipping to the southwest and often much contorted. Mr. G. K. Gilbert‡ crossed

* Map accompanying the report of Dr. C. Hart Merriam on an expedition to Death Valley, compiled under the direction of A. H. Thompson, 1892.

† Geol. Surv. California, Geology., vol i, 1865, p. 459.

‡ Expl. and Surv. west of the One Hundredth Meridian, vol. iii, Geol., 1875, pp. 34 and 169.

the range on the line of the present toll-road from Piper's Ranch to Big Pine. A sketch of the section he made shows a broad syncline on the western side, with faulting and folding in the central and eastern portions. He also gives a section of the rocks exposed on the east face of the Inyo range, at the pass between Deep Spring valley and Owen's valley.*

Mr. W. A. Goodyear, in his account of Inyo County,† notes the contorted condition of the strata, and also gives one sketch of the folding in the strata on the slope of White Mountain, north of Silver Canyon.

During the summer of 1894, accompained by Mr. F. B. Weeks, I crossed the range opposite Big Pine and penetrated into it from the western side, in Waucobi, Black and Silver Canyons, with the special purpose of determining the stratigraphic structure of the western side of the range, after ascertaining that the rocks were of Lower Cambrian age.

My first impression, when passing south through Owen's valley and looking at the west face of the range, was that, from a point twenty miles north of Bishop creek to Tollgate Canyon, the range was formed of a monocline of quartzites, argillites and limestone. The first trip into Tollgate Canyon disproved this, and furnished the data for the tentative conclusion that this portion of the range is a syncline of quartzite and limetones, very much broken by local folding and faulting. This conclusion was verified by the sections exposed in the sides of Black and Silver canyons. I shall first describe the succession of strata exposed on the western slope of the range, as the folding and faulting will thus be more readily understood. From the summit downward the section is as follows:

1. Compact, thin-bedded, arenaceous argillite, with layers of dark-brown, fine-grained quartzite..... 200 ft.
2. Alternating beds of limestone and calcareous and arenaceous shale; a massive bed of limestone, 100 feet thick, near the base..... 1,000 ft.
3. Siliceous slate and compact, dark quartzite..... 2,000 ft.
4. Siliceous limestone, usually in massive beds..... 1,700 ft.

Base unknown.

The limestone series of 2 and 4 are light-colored and contrast strongly with the dark quartzites, argillites and shales. This brings out the more prominent features of structure in bold relief when viewed from the higher points of the western spurs of the range.

* California State Mining Bureau. Eighth Annual Report State Mineralogist for 1888, p. 282.

† In this connection see article in February number on Lower Cambrian Rocks in Eastern California.

Silver Canyon penetrates deep into the range, and about four miles from its mouth cuts across a great synclinal fold. This is outlined in fig. C, page 173. A short distance above the mouth of the canyon the siliceous argillites, with the interbedded layers of quartzite, dip to the eastward about 20°. This dip increases until the beds are in places vertical. Usually at the bed of the canyon there is still a slight eastward dip. As the strata rise on the side of the canyon they become vertical, and finally, about three and one half miles from the mouth, they are overturned to the eastward so as to assume a westward dip and to produce a rough fan structure in the section between the mouth of the canyon and the limestones. The series of argillites and quartzites is broken by minor faults and closely compressed folds. The synclinal structure is clearly shown by the limestone series. The dip of the western limb of the syncline next to the quartzite is from 70° to 80° west. This increases to about 60° near the center of the syncline. The strata of the eastern limb dip westward at about 60° at a point nearest the center, and from that down to 40° near the quartzite.

The section of the syncline exposed on the north side of Silver Canyon is over 2,000 feet in depth, and when viewed from the high ridge on the south side of the canyon, is beautifully exhibited, both in the canyon and in its extension to the northward, along the western face of the range. Frequently the eastern limb of the limestone of the syncline rises to the summit of the range, but as a whole the upper limestone syncline rests against the western side of the range for twenty miles or more north of Silver Canyon.

At the mouth of Black Canyon the lower limestone (No. 4) is exposed. It dips eastward and passes beneath the quartzite (No. 3) at an angle of from 25° to 30°. A fault breaks the section along the line of the north fork of Black Canyon, but by following the section northward about two miles and viewing it from the high ridges to the south of Black Canyon, it is seen that the dip of the quartzites above the limestone increases to the vertical, and at the western edge of the syncline formed by the upper limestone the dip is to the westward.

The lower limestone, owing to the northward pitch of the syncline, passes beneath the Pleistocene beds on the margin of the valley, before reaching Silver Canyon. In fig. B, I have theoretically restored the synclinal section of the range so as to include the lower limestone. What comes out from beneath the limestone on the eastern side of the range is unknown to me, as I was unable to reach that portion of the section. Viewed from the distance, it is apparently a dark-colored rock,

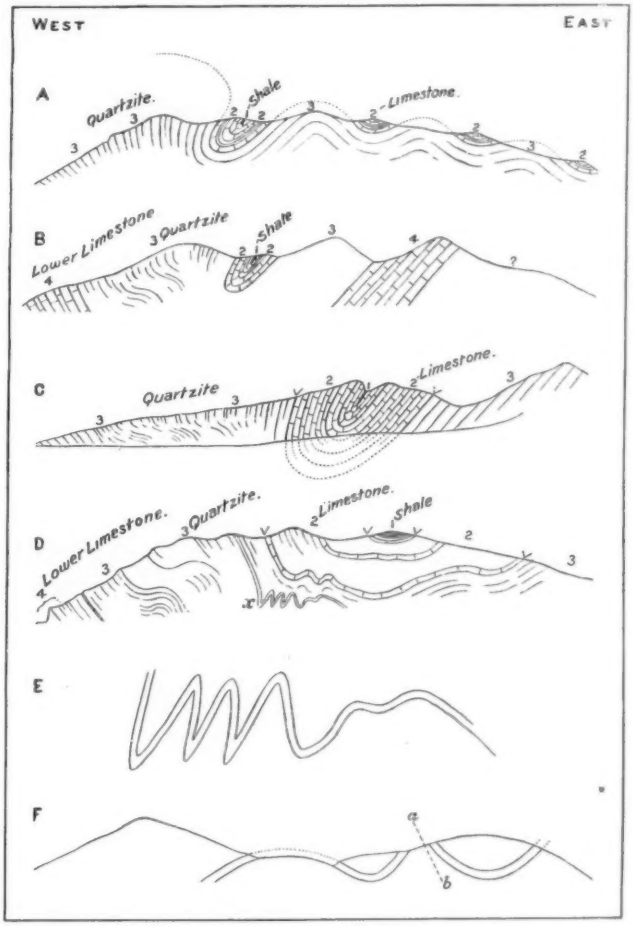
very much broken up and covered with massive granitic eruptives. This is on the line north of Silver Canyon. South of Silver Canyon about five miles, the section as viewed from the high ridge south of Tollgate Canyon is diagrammatically represented in fig. A. The quartzite of the western limb of the syncline is hidden by an intervening ridge, but the syncline of the upper limestone and the two minor synclines to the eastward are clearly defined. The most easterly, on the eastern slope of the range, was not seen at near view, but it appeared to be as represented in fig. A.

The east fork of Black Canyon cuts entirely through the quartzite (No. 3) and into the lower limestone. The syncline has flattened out, and its western limb is nowhere overturned to the eastward. The quartzite (No. 3) is much contorted and broken by minor faults. This is most noticeable about midway of the section and also within a few hundred feet of the upper limestone, where there is a series of sharp anticlinal and synclinal folds, as shown in fig. D, as well as in the enlarged view, fig. E. The depth of these minor synclines is about 300 feet. They appear to have been formed largely by the slipping and compression of a series of argillaceous and thin-bedded quartzites that are between the upper limestone and other portions of the quartzite series. The upper limestones form a broad, somewhat shallow, irregular syncline, upon which, at the summit, rest about 200 feet of arenaceous shales and thin, interbedded quartzites. This shallow syncline extends southward to Tollgate Canyon, where it is much broken, as shown in the sketch made by Mr. Gilbert.* South of Tollgate Canyon there appears to be a broad, broken syncline, with the upper limestone (No. 2) at the summit.

Viewing the White Mountain range from the western slope of the Sierra Nevada, north of Big Pine, it is evident that several transverse or oblique faults break the syncline that rests on the western slope of the range. The strata are displaced on the south side of Black Canyon, and also about five miles to the north. About twenty miles north of Silver Canyon the sedimentary strata are more broken and are apparently covered by eruptive rocks that form the higher portions of the range near White Mountain peak.

The only point that I visited on the eastern side of the range was the section exposed on the northern and western side of Deep Spring valley. On the northern side eruptive granites conceal the greater portion of the sedimentary rocks, but on the western side, nearly southwest of Antelope Spring, are some very fine illustrations of open anticlinal and synclinal folding. This is shown by fig. F.

* Loc. cit.



DESCRIPTION OF FIGURES.

FIG. A.—Diagrammatic section of the White Mountain range as viewed from the high ridge south of Tollgate Canyon. 2, upper limestone; 3, quartzite and shale series.

FIG. B.—Theoretical section of range south of Silver Canyon. to illustrate character of syncline. 2, upper limestone; 3, quartzite and shale series; 4, lower limestone.

FIG. C.—Syncline on the north side of Silver Canyon. 1, upper shale; 2, upper limestone; 3, quartzite and shale series.

FIG. D.—Section on the east fork of Black Canyon. 1. upper shale; 2, limestone; 3, quartzite series; 4. upper portion of the lower limestone.

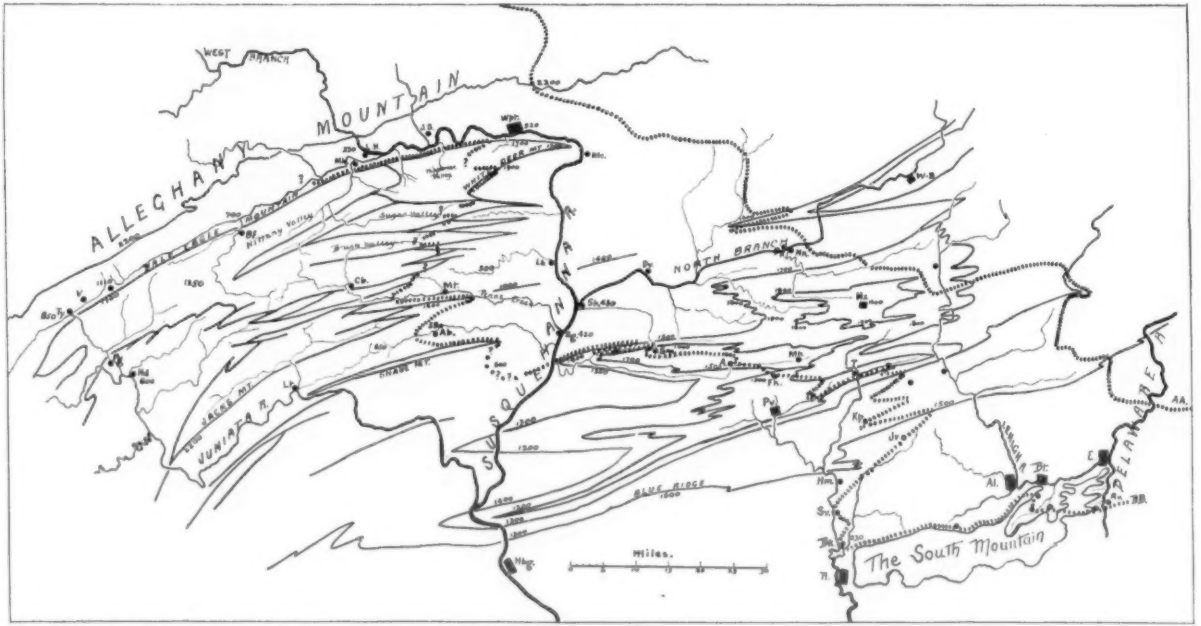
FIG. E.—Anticlinal and synclinal folds occurring at *x* in fig. D.

FIG. F.—Outline of folding of limestone imbedded in quartzite and shales, western side of Deep Spring valley. *a–b*, fault.

As seen from the western slopes of the White Mountain range, the next range to the eastward, Silver Peak, is apparently a monocline facing westward; but from the known structure of the Great Basin ranges, such as those of the Eureka district, Nevada, the Oquirr range, Utah, and others illustrated by the geologists of the Wheeler Survey, it appears that in the broad Paleozoic area between the Sierra Nevada on the west and the early Paleozoic shoreline on the east (Colorado) a period of folding and thrust faulting was followed by a period of vertical faulting, which displaced the strata that had been folded and faulted in the preceding epoch. The extent and character of this disturbance can be determined only by a careful study of each of the mountain ranges for a distance of over five hundred miles east and west and probably a thousand miles north and south; and the great geologic problems will not be fully solved until the areal geology of the region between the 109th and 119th meridians shall have been mapped.

ART. XVII.—*Notes on the Southern Ice Limit in Eastern Pennsylvania;* by EDWARD H. WILLIAMS.

THE accompanying map shows what has been done during the past year, and the boundary has been extended from the Schuylkill to Lock Haven. There probably does not occur as diversified a field, and one more fortunately situated, than that which stretches from the Delaware river to the Alleghany Mountain in Pennsylvania. The measures from the Archæan to the Trias lie under all states of deformation and weathering and, forming all arrangements of mountain and valley, opposed all angles of trend and slope to the approach of the glacier. The lithological and fossiliferous characters of those measures are frequently so well marked that their fragments can be quite readily recognized under all conditions of weathering. The streams of the region run toward all points of the compass, and the Delaware, Lehigh, Schuylkill, and Susquehanna are of constantly large volume, and flow through gaps of great age as shown by their low angles, and over preglacial bottoms. The peculiar systems of parallel ridges and valleys of the region bring great differences in barometric level within small areas; so that the resistance to advance of the ice varied greatly within short distances and, at times, created a shear in the interior of the glacier. The varied river systems also distributed the glacial trash where it could be again taken up by



AA. Moraine of Lewis and Wright; BB. Southern ice limit; A. Ashland; Ab. Adamsburg; Al. Allentown; Bf. Bellefonte; Bk. Berwick; Bl. Berkeley; Bt. Bethlehem; Co. Coburn; Dv. Danville; E. Easton; Hbg. Harrisburg; Hd. Huntingdon; Hm. Hamburg; Hz. Hazelton; Jv. Jacksonville; Kp. Kepner; Lb. Lewisburg; Lt. Lewistown; L.H. Lock Haven; Mc. Muncy; M.H. Mahanoy City; Mh. Mill Hall; Nk. Nescopeck; Pg. Petersburg: Pv. Pottsville; R. Reading; Rv. Riegelsville; Sb. Sunbury; Sg. Selinsgrove; Sm. Shamokin; Sv. Shoemakersville; T. Tamaqua; V. Vail; W. B. Wilkes-Barre; Wpt. Williamsport.

the advancing ice. The glacial discharges and final ablation were made under all conditions of freedom or damming, as the ice-front faced an ascending or descending valley, or rested against a ridge which it could not surmount.

In view of the fact that many writers seem to have forgotten how ice acts in its first advance over a previously unglaciated region, it seems necessary to discuss the subject. Ice erodes and accumulates and, as the country was generally covered, the erosion was of the surface covered, and the accumulations were also from that surface, which, before the advent of the ice, was more or less deeply covered with soil of decomposition. What became of this old soil and its more or less decomposed fragments? In the west, where drainage favored, they were washed away by the glacial floods in the shape of mud and sand, and so distributed that their identity is lost. It is only where drainage has been opposed by the ridges and upward sloping valleys of the Appalachian system, and all waters forced to escape sub-glacially, that we can fully study the deposits of the first glaciation.

The first advance of the ice carried a burden of rotten material. The soft underlying parts were immediately powdered, and whatever resisted immediate destruction was more or less rotted and generally oxidized; but, as it was opposed to a soft surface, its fragments were only rounded into a highly oxidized gravel that was mixed with the clays and sands of the old soil. It was only after a continuance of erosion that the solid rocks were reached and attached to the base of the ice. As this took place at a distance from the ice front, the fresher fragments were carried against the softer surfaces where the ice had as much of a cutting effect as its burden, and no scoring or grooving occurred—only a planing of the surface, as is seen at Rauch's gravel pit at Bethlehem. The fresh fragments finally reached the terminal deposits, and were mixed with the older weathered stuff; but were stirred up with it and are found at all depths, as on the crest of the ridge behind South Bethlehem, where in a rotten, unstratified deposit of great thickness, a fresh Calciferous bowlder lies near an equally fresh Lower Subcarboniferous cobble, on rotten gneiss, and under rotten and angular fragments of Potsdam. When a retreat of the ice took place, and a halt was made at a distance in the rear, the accumulations are generally of fresh fragments, and the thoroughly eroded surfaces show an abundance of groovings and striations. Those who see in this last *all* the work of glaciation, are unfortunate, in that they accept an incomplete sub-stage of the work for its entirety. Secondary advances to the former limits of glaciation frequently fail to remove portions of the former deposits, and cap them with a mass of fresh

material gathered from the rear. Although there may be great differences in appearance, there may be little variation in age, and as it is generally accepted that the erosive power of the edge is slight, we may have a succession of deposits varying from a rotten gravel at the bottom to a fresh one at the surface, and all may have been formed within a short period. Rustiness of gravel, therefore, is no criterion of age, and all arguments based upon it must fall.

The bulk of the deposits is also used by some as an evidence of the duration of glaciation. This is faulty, as regards the first advance, as the first advance evidently removed the rotten surface vastly faster than it did the more resisting rocks at depth; so that comparative estimates based on thicknesses of fresh material on the one hand, and rotten or rusty stuff on the other, are valueless, unless it can be conclusively shown that the rotten and rusty deposit was fresh when formed.

Character of the Deposits.

South of Lewis and Wright's moraine the deposits are generally angular, or sub angular, and rusty accumulations from the old surface. The formations, where exposed, are generally unstriated, and the thickness of till dependent on the contour. In general the determination is made by finding fragments of formations moved out of place in a uniform direction, and independent of the slope. It is a favorable condition when a river which drains a part of the glaciated area crosses the path of another portion of the ice, as the gravels are taken from the river and distributed so as to show the direction of the movement. The broad valleys of the Mauch Chunk (Upper Subcarboniferous) formation are especially useful in marking the ice front, as the contrast between their dark red country rock and the Pottsville conglomerate on the one hand, and the Pocono (Lower Subcarb.) on the other, is so distinct that the erratics are distinguished at a distance. On the other hand, there is little difference between fine fragments of Mauch Chunk and Catskill when weathered, and the latter when leached much resembles Chemung, so that in non-fossiliferous localities the evidences are few and far between. In the event of finding distributed gravels from the rivers, they are uniformly found just over the crest of the ridges opposite to the direction from which they came. This is well shown in going south from Danville to Shamokin. In ten or twelve miles the evidences of glaciation (as shown by river gravels) can be compressed within a few hundred feet. In the valleys well-sections were very useful, and especially when force pumps were necessary from depth of water. Quicksands are found against the

solid glaciated rock in the Wyoming valley and along Penn's creek west of Lewisburg. There was glacial damming in the valleys of the Lehigh, Lizard, Mahoning, and Susquehanna (main and north branch) up to 600 feet in depth; so that glacial deposits are capped by varying thicknesses of slack water clays, and flood cones were formed by torrential discharges into the emponded waters—one of them at Jersey Shore being over a mile in length, 1,000 feet wide and 170 feet high—while the escaping waters distributed gravels over high cols into other river systems, and in one case carried them to within 75 miles of the Potomac. Some points require more extended notice.

The Schuylkill gravels.

At the time when the recent State geological survey was made, the nature of glacial gravels was not so well understood as at present, and the reports on the region state that there are no glacial gravels along this river. There are no striated gravels; but extended patches of unstratified gravels occur at all points along the Little Schuylkill and the main stream, and the writer thinks that the West Philadelphia gravels may be partly glacial, as Mr. Salisbury reports finding glaciated stones at Norristown. The ice covered the whole of the extreme end of the southern coal field from Mauch Chunk to Middleport; so that the upper waters of the Little Schuylkill in the Tamenend valley north of Tamaqua, and the whole valley of Panther creek drained ice covered areas. The extension westward in the Mahoning valley was to the edge of the col between Mahoning creek and the Little Schuylkill, so that some of the glacial waters from that lobe may have reached the latter river at Zeiner's Station. Thence down the river to Port Clinton the gravels are irregularly distributed at low levels, and along the main stream south of the Blue Ridge. About half way between Hamburg and Shoemakersville the upper lobe of the ice from the Lehigh region reached the river and furnished its quota of trash, and at Berkeley the lower lobe did the same. The new Schuylkill Valley branch of the Pennsylvania R.R., cuts through varying thicknesses of unstratified gravels, and especially north of Douglassville. The contrast between the deep red of the Trias and the rusty unstratified cap can be readily seen from the train. The highest elevation above the river of these deposits south of Reading, thus far, has been 30 feet.

The Anthracite regions.

With the exception of the Southern field, west of Middleport, and, perhaps, the extreme western end of the Western

Middle field, the whole of the anthracite area was glaciated. The surface dislocations incident to mining, and the distribution of culm from the coal washings have made a survey difficult as far as connected work is concerned. Points here and there were obtained, and the intermediate line surmised from the contour of the country. As the ice was found to have been at Frackville, it must have crossed the Western Middle basin at Mahanoy Plane; but Mahanoy creek is so clogged with culm as to afford no sign of glacial deposits. As the red shale (Mauch Chunk) valley between Ashland and Gordon showed no erratics the ice did not intrude there; but at Locust Gap till was found, and a thick bed of it lines the creek of the same name at Shamokin; while in the red shale valley to the north trial shafts were sunk through a great thickness of till and bowlders. The records of shafts in many places in this region show that the first part of the work was through "gravel" or "drift." At Trevorton and down Zerbe Run gravels exist; but not as far as Dornsife, where Mahoning creek cuts through the ridge into the Susquehanna Valley. In general, glaciation is shown by the removal of the old soil. At Hazelton in the north, and Shamokin in the south there was a uniformity with which the coal beds came in workable condition to the surface, and with as great relative solidity as the enclosing sandstones. The coal strippings at and about Hazelton show plainly that the glaciation was recent, as, otherwise, the coal beds exposed so near the surface to the action of solvents would have long ere this been turned to black mud, while the sandstones would have retained a good deal of solidity. At Hazelton coal has been mined and marketed where the top rock was entirely removed by glacial action, and only a loose glacial wash capped the bed. The coal was rusty; but solid.

No striations were found over this region; but the Pottsville conglomerate on the ridge just east of Delano (1800–1900 A. T.) is planed over large areas, and large erratics of the same formation are numerous. Where the Pottsville branch of the Lehigh Valley road cuts through the ridge to the Silver Brook basin, the weight and force of the ice bent and crushed the vertical hard bands of Pottsville conglomerate, and the sandstones lying on it, as readily as it did the Hudson River slates south of the Blue Ridge.

The Susquehanna Valley.

The ice moved parallel to the north branch of this river along the Wyoming valley, and crossed it at increasing angles as it neared the main stream at Northumberland. The bed of the branch is generally solid rock, with the inequalities filled

with glacial trash. Much discussion has been held regarding the Berwick gravels, and some have held that they were due to a submerged mouth of the river. As the ice went 25–30 miles south of the place, their origin is no longer in doubt; but the freshet of last May disclosed the nature of these deposits perfectly, as the torrential state of Nescopeck creek which reaches the river opposite to Berwick, cut away ten feet of the north bank of the creek at the Pennsylvania R.R. bridge; so that the north abutment was isolated and undermined. As this cut was vertical and the material compact it was seen that there was the same succession of events as shown in the Lehigh Valley at Rauch's gravel pit. There are three formations in the gravels at Nescopeck and Berwick: first, sub-glacial till so compact that a pick can scarcely be driven into it. This has a clay base and carries an abundance of rolled stones of all the formations to the north—even granite and anthracite meet in the mass. On this is a bed of modified drift of loose nature and sandy matrix with the same collection of rolled stones and of equal freshness. In fact, there is no difference in the color of the layers. As at Rauch's pit the lower inch of the gravels is a conglomerate with a limonite matrix, where the percolating waters laden with the solution of iron were stopped by the dense till below. Capping all is a layer of unstratified sand that varies in thickness greatly within a few feet, and carries streaks of gravel and glaciated cobbles and bowlders at all levels. We have, therefore, the till from the ice on the spot, and the modified drift when the ice was in retreat; but in the vicinity, and, finally, the sands, when the ice had retreated to a distance and the torrential nature of the stream had ceased; but when there still were discharged bergs bearing burden of large material. It is about 20 feet from the rock bottom of the river to the top of the sandy cap.

There are several low kames along the north branch; but their formation could not be studied from absence of cuttings.

The ice crossed the valley of the west branch from Northumberland to Muncy at the same angle as in the other branch, and the formations are similar in succession; but from Muncy westward a slack water-cap hides whatever is below, and it is only where the cuttings are fresh that the succession can be seen.

In the main valley the southern limit of the ice was where Little Mountain reaches the river. As this rises abruptly 1000 feet above the country it proved an effectual barrier to a farther southern advance. The glacier crossed the river and seems to have reached the northeastern end of Shade Mountain, as there was a slight flow southwestward over the low col of 200 feet into the Juniata at Lewistown. Evidences of glacia-

tion are also seen in the distribution of the white Medina sandstone of Shamokin Mountain over the Salina valley to the southwest. Farther north along Penn's creek an abundance of modified drift is seen capping till of quicksands and bowlders that lie against the glaciated country rock, and all is covered with slack water clays from the Shade Mountain ice dam, or the one formed before the ice abandoned the northern end of Jack's Mountain.

Action of the ridges on the ice advance.

A glance at the map shows the numerous ridges crossing the path of the glacier. These rise sharply from the surrounding country to 600–1000 feet. The retention of a large mass of rotten gneiss on the northern slope of the South Mountain back of South Bethlehem, and where it was fully exposed to the force of the ice seemed to point to a massing of the ice in the valley, where it remained stagnant, while a shear took place and the upper part of the ice only crossed the mountain. This is also shown by the small proportion of river gravels in the till—though the glacier had just crossed the Lehigh.

In Report G7 of the late Pennsylvania survey, I. C. White describes the glacial deposits in the tier of counties along the north branch of the Susquehanna. As far as the knowledge of the subject went at that date, the report is accurate. One point is interesting in its bearing on glacial motion. In describing the gravels in Mifflin township he notes their occurrence only at comparatively low elevations above the river. The writer found this to be the case, and made a trip over Nescopeck Mountain while studying the matter. It seemed strange that the narrow strip of land lying between the Susquehanna and the mountain should be free from gravels, while to the west they were found distributed regularly over the country for many miles south of the river and in some cases 500 feet above it. The map shows that Nescopeck Mountain rises 1000 feet above the river and runs parallel to it for some miles and, at Catawissa (as Catawissa Mountain) turns southward in a series of folds, and finally resumes its former trend, as Little Mountain, and reaches the Susquehanna. At first it was thought that the mountain turned the glacier wholly from its path and forced it to scrape along its northern flank till its bend at Catawissa withdrew the resistance, when the released ice resumed its former line of motion; but the finding of till on the summit of the mountain, and also erratics from its summit that were carried across Scotch valley and over McCauleys Mountain, showed that the ice crossed it. Had this been done in the general line of motion, the abundant river gravels would

have been found at all elevations over the mountain. As they stop, at the mountain foot, and as the till on the flanks and top is angular and from the immediate neighboring formations, or consists of large bowlders of the sandstones to the north, it is evident that the lower part of the ice moved parallel to the river and mountain, while the upper part crossed the ridge and probably united with the lobe that came from the east along the enclosed valley south of Nescopeck Mountain.

The glacial gravels of the Juniata valley.

While studying the deposits in the valley of the Susquehanna, the writer followed a line of drainage over the low divide between the Susquehanna at Selin's Grove and the Juniata at Lewistown; but was surprised to find on the Salina bluffs south of the river, at the latter place, a series of lenticular deposits of glacial gravels and bowlders in the depressions and on the down-river side of the elevations of those bluffs, and at heights up to 80 feet above the river. Their position pointed to an origin up the Juniata; but as I was engaged in regular work, I let that matter go for the time; but looked up the authorities and found that I. C. White, in his report for Huntingdon county in the recent survey of the State, noted their appearance in that county, and advanced four theories for their origin; but without favoring either of them; while those who worked in Mifflin and Juniata counties said nothing of the occurrence of gravels at such high elevations.

As Professor White* had also reported upon the counties along the north branch of the Susquehanna, he was in a position to speak regarding glacial deposits, and in the Huntingdon report (p. 31) he says, "Great heaps of bowlder trash, both rounded and angular, are often to be seen along the valleys of the principal streams; and these often very much resemble genuine drift heaps; but no *striated* bowlders or *striated* fragments of the country rock are to be found in the region." He further reports them at elevations above 100 feet from the river. The hypotheses advanced are various, and the only one of value is that of the melting snows of the glacial period that kept all the rivers of the State at a higher level than at present. Nothing is said of glacial occupation of the region.

* Justice to Professor White requires the statement that his work in the recent geological survey of Pennsylvania was confined to counties widely separate from one another; so that the study of a limited portion of the Juniata valley would afford no clew to the origin of these gravels, had it not been supplemented by extended work over a large adjacent area. The writer was fortunate in having the careful and accurate work of Professor White to guide him in the study of the north branch of the Susquehanna, and has many times regretted that it was not extended to the south and west; as those regions were treated from an entirely different standpoint.

It is to be noticed that nothing is said of any difference in age between these drift heaps and those of the great moraine. There is no difference, in fact, and as the writer was happy in finding glaciated stones at Lewistown, he set the deposit down as a recent glacial formation, and as recent as the glacial gravels of the upper Susquehanna.

A glance at the map of Lewis and Wright shows that the terminal moraine approaches quite near the north branch of the Susquehanna at Williamsport. As the width of the extra-morainic deposits will average 25 miles, the writer saw, when he reached the latter place, that Bald Eagle Mountain, rising sharply 1200 feet above the river, must have required a great thickness of ice to have been surmounted, and must have formed a glacial lake similar to that in the Lehigh valley, as has been described by the writer. In proof of this the surface deposits west of Muncy changed to slack water clays and overlaid, where visible, modified and unmodified drift. A trip through the gap in Bald Eagle Mt., to the inner summit of White Deer Mt., lying three miles to the south, and making a loop with the former where they meet the Susquehanna, showed that ice had surmounted both, and, as the glacier had crossed the main Susquehanna at Fisher's Ferry, at the northern slope of Little Mt., there was at least fifty miles of the bed on the stream covered with ice over 1200 feet thick. Previous to this a line of glacial discharge had been traced up Penn's Creek to Paddy Mountain; but its origin was unknown.

Going west up the valley of the north branch of the Susquehanna, a great slack water terrace 150–170 feet high was found opposite Jersey Shore, which causes the river to make a long bend to the north and east. This was formed by a torrential discharge of glacial origin from Nippenose valley through Anti's gap in Bald Eagle Mt. Rogers has called attention to the peculiar features of the erosion of the south side of this valley, and to the "drift hill" in the gap. He also notes a similar hill in Washington gap between Sugar and Nittany valleys. The Jersey Shore terrace surprised the writer by bending to the northwest, and the stream that drains Nippenose valley was also surprising in meeting the Susquehanna in a similar way, or against the present flow of the river. Both pointed to a flow westward. A glance at the map showed that the Bald Eagle and Nittany valleys would afford an exit to deep waters, and the latter valley was first studied with the result that no signs of ice occupation were found; but it was seen that Sugar and Brush valleys had their eastern ends covered with ice, and that the northern end of Nittany valley was covered deeply with bowlder trash, as was the part adjacent to the gaps from the valleys to the east. From Bellefonte east-

ward to the valley of Penn's creek the surface was clear, but the glacial flow through that creek was seen to have come from Brush valley.

At Mill Hall twelve feet of slack water deposits overlie what seems to be sub-glacial till, and the Bald Eagle valley soon becomes perfectly flat and filled with debris, from which the small knolls formed by varying outcrops appeared in a submerged state. These deposits were followed continuously over the divide at 1110 A. T., or 600 feet above the river at Williamsport, and down the Juniata to Huntingdon. Wherever they exist at great depths in the latter valley there is evidence of slack water, as below them there is a contraction of the channel, where it passes through the gaps in the numerous ridges. When we consider that the whole discharge from the central part of the state glacier passed through Bald Eagle and Juniata valleys, we can see at once that small ice dams must have been continually forming in these narrow gorges, from the floating bergs, and as these deposits are found from the present level of the river to an average of 80 feet above it, we can get an idea of the depth of the water. In one case, a dam sent cakes of ice from 300–400 feet up the slope of Warrior Ridge to make a small deposit of erratics. That the discharge was torrential is seen by the erosion of the rotten limestone at Barree on the up-stream side of the ridge, and its retention on the other side to great depths. We can imagine, therefore, during a portion of the earliest part of glacial times, a deep lake extending from Williamsport above the junction of the Susquehanna and Sinnemahoning; filling Nippenose, upper Nittany and Bald Eagle valleys, and discharging a deep torrent through the Juniata. A smaller side discharge from the same glacier went down Penn's creek to the Susquehanna; but was stopped by the ice at Shade Mt. for a time and sent down to Lewistown, on the Juniata; but afterwards was freed and allowed to reach the Susquehanna at Selin's Grove. This great glacial lake has been called by the writer, in honor of our State geologist, Lake Lesley.

Detailed sections were photographed at various places through the Bald Eagle and Juniata valleys. At the northern entrance of the former, at Mill Hall, there is a considerable flood cone attached to the southern side of the gap in Bald Eagle Mt., where the flow was turned south from the Nittany valley. Along the Central railroad of Penn., through the latter valley, there exist thick deposits of glacial drift distributed from the gaps to the east, and the larger material lies close against the Nittany Mt. on the eastern side of the valley, while the fine clays extend over the whole valley. The flood cone at Mill Hall, therefore, does not contain gravel in its

upper, slack-water part; but only clay and fine fragments of the local Devonian rocks. This lies on what seems to be subglacial till; but the exposures were so small, and the time for study so short that it may have been a hard clayey modified drift. At any rate it was dense and unstratified. One argument in favor of its being till was that it lay on rotten local rock from which the old surface had been removed. Going south along Bald Eagle valley the inequalities of the valley are covered by gravel in the place of the Mill Hall drift, and that is capped by slack water sands and clays—all unstratified. This shows that the action was continuous. On crossing the divide the modified drift continues at varying thicknesses; but always unstratified, and the slack water clays of the northern side are replaced by sands and fine stuff as the torrential nature of the flow gradually ceased. An excellent section is seen in the creek at Vail—about 125 feet below the divide, and the same distance above the Juniata at Tyrone. At East Tyrone, in the yard of the Pennsylvania R. R., many fine sections are shown, and the succession is similar to those described. Huntingdon is built on a flood cone where the Juniata pours through a narrow gorge into a wide cross valley.

Art. XVIII.—*The Succession of Fossil Faunas at Springfield, Missouri;* by Stuart Weller.

Introduction.

The rocks under consideration in this paper, are those lying above the yellow Chouteau limestone in the region in question. They consist of beds of gray limestone, more or less crystalline in the various strata, with scattered bands of lenticular chert concretions. No results of careful stratigraphical work, based on palæontological evidence, have ever been published in connection with this region, and though the rocks have been correctly considered as equivalent to that part of the Mississippian Series known in Illinois and Iowa as the Burlington and Keokuk Groups, the subdivisions of the strata have never been properly pointed out. The object of the present paper is to dissect out the various sub-faunas, to note their order of succession and the relations which they hold to each other.

During the summers of 1892 and 1893 the writer made quite extensive collections of the fossils from the quarries and other exposures in and about Springfield. From the study of these collections, the whole series of strata has been divided into twelve zones, which can be distinguished by their faunas.

The limits of these zones, however, are not sharply defined, as lower faunas change to the ones above through gradual transitions.

As the fauna of the Keokuk beds in Illinois and Iowa has been shown to be simply a later product of the same line of development which took place during the deposition of the Burlington beds, so here in Southwest Missouri, the upper faunas, which represent the Keokuk, are only a continuation of the development seen in the lower beds. Prof. H. S. Williams has suggested the name Osage Group* for this whole series of strata in Missouri, while Mr. C. R. Keyes has adopted the name Augusta Group† for the same deposits. With the exception of the lowest beds, the Springfield limestones resemble their more eastern equivalents in Illinois and Iowa, both in lithological and in faunal characters.

The great difficulty experienced in this study, has been the lack of any continuous section comprising all the beds of the group, such as is shown in the Mississippi River section. Some twenty-five localities were studied, and from them more or less complete collections of the fossils were made.

Most instructive in the way of showing the succession of the faunas, is a series of sections along the Gulf railroad, from Jones Spring, four miles southeast of Springfield, to the Gulf railroad shops in the city, then turning to the south and extending along Wilson Creek to Mackey's quarry. These sections show the succession from near the base of the Burlington up into the Keokuk. Along this line the rocks dip gradually to the west, and in the successive cuts and quarries, starting from Jones Spring, successively higher beds are exposed. At one point, a short distance east of Springfield, a slight fault disturbs the regularity of the line of sections, otherwise it is continuous. Besides this series of sections, other more or less isolated outcrops were studied.

There being no continuous section, and the element of dip being uncertain, no accurate estimate of the aggregate thickness of these beds can be made, but they probably extend through one or two hundred feet.

Description of Zones.

Zone I.—This zone can be readily recognized wherever it occurs. Its lithological characters are, in general, distinct from any of the succeeding beds. It is a fine-grained, gray or bluish limestone, quite hard, and with a more or less marked conchoidal fracture. Some lenticular chert nodules occur

* Bull. U. S. Geol. Surv., No. 80, p. 109. Washington, 1891.
† Iowa Geol. Surv., vol. i, p. 59. Des Moines, 1893.

scattered through the limestone. Its geological position is immediately above the yellow Chouteau limestone, and in some places it even seems to be a continuation of the Chouteau, with no sharply fixed dividing line; the yellow, sandy Chouteau gradually changing in color and texture till it becomes this hard gray limestone. Also the two faunas are blended so that the association of organic forms occurring here, is transitional between the Chouteau and the true Burlington. The zone is characterized by a brachiopod fauna.

At Spout Spring (Station 21), the following fauna was collected a few feet above the yellow Chouteau.*

**Spirifer biplicatus* Hall.
†*Productus lævicostus* White.
Productus sp.
**Terebratula burlingtonensis* White.
†*Spirifer lineata* Martin.
†*Spirifer suborbicularis* Hall.
†*Chonetes illinoisensis* Worthen.
†*Orthis swallovi* Hall. ?
Spiriferina sp.
**Phanerotinus paradoxus* Winchell.
**Entolium circulus* Shumard.
†*Productus punctatus* Martin.
†*Productus burlingtonensis* Hall.
†*Terebratula cf. hastata* Sowerby.
Loxonema sp.

The most abundant species, *S. biplicatus*, is described from the Kinderhook. The remaining forms are partly Chouteau and partly Burlington. The species which range downward are comparatively rare.

Collections have also been made from this zone near Pierson Creek, east of Springfield (Station 17). Here the fossils are from an horizon higher above the Chouteau than at Spout Spring, but the lithological characters are similar, except that the limestone contains much more chert. The following species were collected at this locality.

†*Chonetes illinoisensis* Worthen.
†*Orthis burlingtonensis* Hall.
Spiriferina sp.
†*Spirifer suborbicularis* Hall.
**Spirifer biplicatus* Hall.
**Spirifer marionensis* Shumard.
†*Spirifer grimesi* Hall.
†*Athyris lamellosa* L'Eveille.
Phillipsis sp.
†*Derbyia keokuk* Hall. ?

The fauna differs in some respects from the Spout Spring fauna, and more nearly resembles the true Burlington.

At an exposure on Sac Creek (Station 20), other collections were made which may be referred to this zone. The beds are of an higher horizon than either of the preceding localities, being up very close to the crinoidal limestone of the Burlington beds proper. In this fauna species of higher range are more common but lower forms are still present. The following species were collected.

* Species marked * are forms having a downward range, and those marked † range upward. In all the lists the species are arranged according to their relative abundance, the most abundant being placed at the beginning of the list.

Chonetes illinoisensis Worthen.
Spirifer biplicatus Hall.
Syringothyris carteri Hall.
Spirifer suborbicularis Hall.
Rhynchonella sp.
Spiriferina sp.
Terebratula sp.
Orthis burlingtonensis Hall.
Orthis swallovi Hall.
Strophomena analoga Phillips.
Derbyia keokuk Hall.
Athyris lamellosa L'Eveille.
Productus burlingtonensis Hall.
Spirifer lineata Martin.
Athyris incrassatus Hall.
Spirifer grimesi Hall.
Productus lævicostus White.
Productus punctatus Martin.
Spirifer forbesi Norwood and Pratten.
Platyceras sp.

Spirifer biplicatus, a lower form which was abundant in the Spout Spring fauna, is still one of the common species. *Spirifer grimesi* which is the most characteristic brachiopod of the Burlington limestone, is rare in this whole zone.

The contact between Zone I and the overlying beds is generally quite well defined lithologically, but in some cases the transition between the two is gradual.

Zone II.—The lithological characters of the beds of this zone are decidedly different from those below. Here we pass into beds of rather coarse, crystalline limestone, composed largely of broken crinoid fragments, the fauna is a typical Burlington one.

At Jones Spring (Station 1), these beds are exposed lying directly upon the more compact limestone of Zone I. The following fauna was collected at this station.

Spirifer grimesi Hall.
Spirifer keokuk Hall. ?
Productus sp.
Athyris lamellosa L'Eveille.
Chonetes illinoisensis Worthen.
Straparollus latus Hall.
Spirifer suborbicularis Hall.
Strophomena analoga Phillips.
Orthis burlingtonensis Hall.
Zaphrentis centralis Worthen.
Platyceras sp.
Productus sp.
Syringothyris plenus Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.

In a quarry at the Valley Water Mills (Station 18), the following species were collected, lying immediately above Zone I.

Spirifer grimesi Hall.
Athyris incrassatus Hall.
Orthis swallovi Hall.
Strophomena analoga Phillips.
Straparollus latus Hall.
Athyris lamellosa L'Eveille.
Spirifer forbesi Norwood and Pratten.
Derbyia keokuk Hall.
Platyceras sp.
Zaphrentis centralis Worthen.
Syringopora harveyi White.

In a quarry at Edward's Spring (Station 19), in strata a short distance above those containing the last fauna described under Zone I, these beds are well exposed. Here the two zones are not sharply defined lithologically, but the lower one grades gradually into the upper. Two more or less distinct beds are recognized in this quarry. From the lower of these the following fauna was collected.

Productus sp.
Straparollus latus Hall.
Productus sp.
Spirifer sp.
Strophomena analoga Phillips.
Agaricocrinus planoconvexus Hall.
Spirifer keokuk Hall.
Spirifer suborbicularis Hall.
Derbyia keokuk Hall.
Orthis swallovi Hall.
Dichocrinus striatus Owen and Shumard.
Pleurotomaria montezuma Worthen.
Syringothyris plenus Hall.
Platycrinus sp.
Chonetes illinoisensis Worthen.

In the upper bed the fauna is somewhat different.

Spirifer suborbicularis Hall.
Productus sp.
Chonetes illinoisensis Worthen.
Orthis swallovi Hall.
Batocrinus pyriformis Shumard. ?
Spirifer lineata Martin.
Zaphrentis centralis Worthen?
Platyceras sp.
Productus burlingtonensis Hall.
Spirifer keokuk Hall. ?
Spirifer grimesi Hall.
Syringothyris plenus Hall.
Spirifer forbesi Norwood and Pratten.
Spirifer sp.
Terebratula cf. hastata Sowerby.
Athyris lamellosa L'Eveille.
Dichocrinus striatus Owen and Shumard.
Athyris trinuclea Hall. ?

Most of the species occurring in this zone are typically Burlington forms. A few are limited to this horizon while others begin here and only reach their maximum development higher up.

Zone III.—In this zone the limestone is very similar to, and is a direct continuation of Zone II. At Station 2 these beds are exposed, and their position above Zone II can be readily seen. The following fauna was collected.

Syringothyris plenus Hall.
Spirifer grimesi Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.
Orthis burlingtonensis Hall.
Spirifer suborbicularis Hall.
Athyris incrassatus Hall.
Spirifer sp.
Eucladocrinus pleurovimineus White.

At Station 14 the following species were collected from the same zone.

Syringothyris plenus Hall.
Spirifer grimesi Hall.
Productus burlingtonensis Hall.
Athyris incrassatus Hall.
Spirifer suborbicularis Hall.
Spirifer sp.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Orthis swallovi Hall.
Cladodus sp.
Platyceras quincyense McChesney.
Athyris lamellosa L'Eveille.
Terebratula cf. hastata Sowerby.
Dichocrinus striatus Owen and Shumard.

At Station 13, in beds of the same zone but probably at a little higher horizon, the following fauna was collected.

Syringothyris plenus Hall.
Chonetes illinoisensis Worthen.
Orthis swallovi Hall.
Spirifer grimesi Hall.
Productus burlingtonensis Hall.
Athyris incrassatus Hall.
Orthis burlingtonensis Hall.
Productus setigerus Hall.
Spirifer sp.
Spirifer suborbicularis Hall.
Metoptoma umbella Meek and Worthen.
Zaphrentis centralis Worthen.
Hadrophyllum glans White.

The distinctive character of this zone is the presence in large numbers of *Spirifer grimesi* and *Syringothyris plenus*, associated with *Orthis swallovi*, *Productus burlingtonensis*, etc. All the Chouteau species have disappeared and the fauna is typically Burlington. Exposures of the intermediate beds between this zone and the one below, have not been observed, but the change from one fauna to the other is probably very gradual, *S. plenus*, *S. grimesi*, etc., becoming more and more the predominant forms and replacing the smaller species which were abundant in Zone II.

Zone IV.—At Station 12, three distinct beds of limestone are exposed. The lowest of these is very similar in character to Zone III at Station 13, and probably lies but very few feet above it. However, there is a decided change in the fauna. *S. plenus* which was the most abundant species in the preceding zone, has almost entirely disappeared.

At Station 12, the following species were collected in the lowest bed.

Spirifer grimesi Hall.
Orthis swallovi Hall.
Orthis burlingtonensis Hall.
Athyris incrassatus Hall.
Productus punctatus Martin.
Metoptoma umbella Meek and Worthen.
Spirifer lineatoides Swallow.
Platyceras quincyense McChesney.
Platyceras equilatera Hall.

In the excavation made a few years ago at Station 6, the same three beds of limestone were penetrated as are seen at Station 12. Some fossils were obtained from here at the time, but they were not collected with reference to the present work. In the bottom of the excavation a coarse, gray, crystalline limestone, like the lower bed at Station 12, was exposed, and a great number of large, fine specimens of *S. grimesi* were collected, but no specimens of *S. plenus*.

Northwest of Springfield, in a large sunk hole (Station 15), a stratum of gray, crystalline limestone is exposed, with numerous fossils. Prominent among them is *S. grimesi*, but not a specimen of *S. plenus* was seen. The fauna as a whole is very similar to those just described and may be placed with them in Zone IV. The species collected are as follows:

Chonetes illinoisensis Worthen.
Spirifer grimesi Hall.
Orthis burlingtonensis Hall.
Spirifer sp.
Athyris incrassatus Hall.
Productus setigerus Hall.
Platyceras equilatera Hall.
Athyris lamellosa L'Eveille.
Productus punctatus Martin.
Platyceras quincyense McChesney.
Spirifer suborbicularis Hall.
Orthis swallovi Hall.
Derbyia keokuk Hall.
Zaphrentis centralis Worthen.
Rhynchonella cf. pleurodon Phillips.
Metoptoma umbella Meek and Worthen.
Hadrophyllum glans White.
Phillipsia bufo Meek and Worthen. ?

The fauna of the beds exposed at Station 16 is intermediate between the faunas of Zones III and IV. Both *S. plenus* and *S. grimesi* are abundant, though *S. grimesi* is the more common. Some other species, more characteristic of Zone IV, are present and therefore this fauna has been placed with Zone IV. The following is a list of the species collected.

Chonetes illinoisensis Worthen.
Spirifer grimesi Hall.
Spirifer sp.
Syringothyris plenus Hall.
Productus setigerus Hall.
Orthis burlingtonensis Hall.
Spirifer suborbicularis Hall.
Orthis swallovi Hall.
Productus punctatus Martin.
Athyris incrassatus Hall.
Zaphrentis centralis Worthen.
Spirifer lineatoides Swallow.
Athyris lamellosa L'Eveille.
Spirifer sp.

The whole fauna of this zone is interesting on account of the large size of the species. A constant increase in the average size of the members of the fauna as a whole, from Zone I to Zone IV is evident. In Zone I all the species are small, while in Zone IV nearly all are very large. This increase in size may be traced out even in a single species or a race. The earliest examples of *Spirifer grimesi* are generally small, but in the successively higher beds the average size increases till the maximum is reached in Zone IV. During this increase in size the specific characters remain unchanged, but above Zone IV, as the species becomes again reduced in size, the specific characters change and the race is represented by *S. logani.*

The *lineata* type of *Spirifers* also illustrates this same principle, but in this case, with the increase in size, new specific characters are assumed. The race is represented in Zones I and II by *S. lineata*, which is scarcely ever more than one-half inch in breadth. In Zone III *S. pseudolineata* occurs. This is a larger species with coarser markings. *S. lineatoides*, which is a still larger and coarser form of the same race, is limited to Zone IV. As this race decreases in size, it seems to pass through the same stages by which it attained its maximum development, but in a reverse order, for in beds above Zone IV, *S. pseudolineata* occurs which cannot be distinguished from specimens in Zone III. Other species illustrating the same principle, and reaching their maximum development at nearly the same horizon, are *Athyris lamellosa*, *Orthis swallovi*, *Zaphrentis centralis*, and *Platyceras.*

Zone V.—Lying above Zone III at Station 12, and also at Station 6, is a bed of much more siliceous limestone. This lower chert bed, as it may be designated, is constituted of variable proportions of a white, calcareous chert in lenticular masses, and limestone. The limestone is variable in character, but in general is much finer grained and harder than the beds below or above, and it often resembles very closely the fine

grained limestone of Zone I. The chert, when subjected to the influence of weathering, slacks to a fine white powder. In many cases the chert masses surround a nucleus of limestone, the passage from the one material to the other being very gradual. Often fossils retaining their calcareous condition are found embedded in the chert. Like the limestone below, this also is largely made up of crinoidal remains, but perfectly preserved bodies are much more common.

At Station 12 the following fauna was collected.

Spirifer grimesi Hall.
Athyris incrassatus Hall.
Dorycrinus parvus Shumard.
Physetocrinus ventricosus Hall.
Orthis swallovi Hall.
Agaricocrinus americanus Roemer.
Platyceras sp.
Actinocrinus verrucosus Hall.
Terebratula cf. hastata Sowerby.

At Station 6 very few fossils were collected from this zone, but *Athyris lamellosa* was seen in addition to those mentioned. However at this locality we have the chert bed, with the same character of chert and limestone, lying in the same position as regards the fauna with the great development of *Spirifer grimesi*, and there can be no doubt as to the equivalence of the beds at the two localities.

In the Gulf R.R. section this chert bed is exposed at two other localities besides Station 6. At Station 3 about eight feet of this stratum is exposed. Only two species of fossils were collected here, though others are present.

Spirifer grimesi Hall.
Dorycrinus parvus Shumard.

At Station 4 this bed is again exposed. No fossils were collected here, but in the face of the quarry *Spirifer grimesi* and *Athyris incrassatus* appear to be common.

This zone may be considered as the upper limit of the true Burlington, and can be recognized by the peculiar character of the limestone and chert, as well as by its fauna. In this region *Dorycrinus parvus* is characteristic of the horizon.

Zone VI.—Lying above the lower chert bed is an horizon of rather coarsely crystalline limestone, much like that which also occurs below the chert. Nearly all the quarries along the south bank of Wilson Creek, in Springfield, are in strata of this zone. The beds however, dip to the west, and being carried below the surface, higher beds are exposed in the quarries near the Gulf R.R. shops.

At Station 3 the base of this zone may be seen resting directly upon the chert beds below. Fossils are abundant at this locality and the following species were collected.

Spirifer grimesi-logani Hall.
Zaphrentis varsoviensis Worthen.
Athyris incrassatus Hall.
Zaphrentis centralis Worthen.
Chonetes illinoisensis Worthen.
Synbathocrinus swallovi Hall.
Phillipsia bufo Meek and Worthen.
Spiriferina sp.
Platycrinus saffordi Troost.
Batocrinus subtractus White.
Batocrinus pyriformis Shumard.
Granatocrinus granulosus Meek and Worthen.
Platyceras equilatera Hall.
Athyris lamellosa L'Eveille.
Orthis swallovi Hall.
Derbyia keokuk Hall.
Productus sp.
Agaricocrinus americanus Roemer.
Batocrinus trochiscus Meek and Worthen.
Spirifer suborbicularis Hall.
Productus setigerus Hall.
Productus punctatus Martin.
Dorycrinus cornigerus Hall.
Actinocrinus multiradiatus Shumard.
Cyathocrinus iowensis Owen and Shumard.
Amplexus fragilis White and St. John.
Productus burlingtonensis Hall.

This fauna is interesting because of its transitional forms. There can be little doubt but that this horizon in Southwest Missouri may be correlated with the Burlington–Keokuk transition beds in Iowa. The fauna contains numerous crinoids, and the similarity between the forms collected here, and those described by Wachsmuth and Springer* from the transition beds at Burlington, Iowa, is very striking. The large *Spirifer* so abundant here is also a transitional form. It is the representative of what has been called *Spirifer grimesi* in the Burlington beds below, but at this horizon it begins to lengthen its hinge line and to assume the characters of *Spirifer logani* of the succeeding beds. Here however the *grimesi* type is most abundant, the individuals with elongated hinge lines being uncommon, and even in those which are present the character is not so extremely developed as it is higher up.

Above the lower beds of this zone, fossils are not so abundant. At Station 5 the following species were collected.

Spirifer grimesi-logani Hall.
Phillipsia bufo Meek and Worthen.
Athyris incrassatus Hall.
Orthis swallovi Hall.
Productus burlingtonensis Hall.
Spirifer suborbicularis Hall.
Derbyia keokuk Hall.
Zaphrentis centralis Worthen.
Platyceras fisurella Hall.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Syringothyris texta Hall.
Athyris planosulcata Phillips.
Palæacis obtusus Meek and Worthen.
Spirifer sp.
Aviculopecten magna Swallow.

Zone VII.—The next higher horizon studied, having a distinct fauna, is exposed in the upper part of the quarry at Station 7. The bed is largely composed of chert, and may be designated as the upper chert bed. The chert here is very different from that in Zone V. It is very hard and brittle and much stained with iron, and occurs in much larger and more irregular masses than in the lower bed. Both the chert and the limestone abound in fossils, but in all cases the calcareous matter of the fossils contained in the chert has been dissolved out, leaving the fossils in the form of moulds. In these impres-

* Proc. Phil. Acad. Nat. Sci., 1878, p. 224.

sions in the chert, the finest detail of the surface markings of the shells are preserved. The limestone is coarsely crystalline and is largely composed of crinoid remains. On the decomposition of the limestone, the chert remains in the soil, often forming regular strata in the residual clay beds. Much of the fossiliferous chert, so abundant in the soil of this region, is from this horizon.

The fauna collected at Station 7 is as follows.

Agaricocrinus americanus Roemer.
Spiriferina sp.
Terebratula sacculus Martin.
Athyris incrassatus Hall.
Platycrinus saffordi Troost.
Eretmocrinus originarius Wachsmuth.
Spirifer logani Hall.
Orthis dubia Hall.
Batocrinus biturbinatus Hall.
Pentremites conoideus Hall.
Spirifer pseudolineata Hall.
Derbyia keokuk Hall.
Batocrinus sp.
Granatocrinus granulosus Meek and Worthen.
Spirifer tenuicostatus Hall.
Spirifer neglectus Hall.
Spirifer suborbicularis Hall.
Productus setigerus Hall.
Eumetria verneuilana Hall.
Batocrinus nashvillæ Troost.
Platyceras fisurella Hall.

This is decidedly a Keokuk fauna, and here we find the first appearance of a large number of new forms. Crinoids are abundant, but only the more delicate Keokuk forms are present. The crinoidal fauna does not assume the grotesque character so noticeable among the crinoids of the Keokuk Group in Iowa. The *tuberosus* variety of *Agaricocrinus americanus* is the only representative of these large forms.

Zone VIII.—The upper chert bed is succeeded by beds of crinoidal limestone similar to those which precede it. These strata may be seen at Station 8, and the fauna collected there is as follows:

Spirifer logani Hall.
Phillipsia bufo Meek and Worthen.
Zaphrentis centralis Worthen.
Productus punctatus Martin.
Derbyia keokuk Hall.
Rhynchonella mutata Hall.
Chonetes illinoisensis Hall.
Orthis dubia Hall.

At Station 9 the same horizon is exposed and the following species were collected.

Spirifer logani Hall.
Spirifer suborbicularis Hall.
Productus punctatus Martin.
Camarophoria subtrigona Meek and Worthen.
Derbyia keokuk Hall.
Terebratula sacculus Martin.

The fauna of this zone is Keokuk, though many species which were common in the chert zone, apparently are absent here. The reappearance of *Chonetes illinoisensis* is interesting, it being a form especially abundant in the Burlington beds below. Among the specimens of *Spirifer logani* the character of a lengthened hinge line is more exaggerated than in the beds below, but above this zone it is a rare species.

Zone IX.—This zone, as well as the three succeeding ones, with the exception of Zone XI, have only been seen in Mackey's

quarry, Station 11. The section at this station is as follows, beginning with the lowest stratum.

1. Six feet of coarse, gray, crystalline limestone with many fossils.
2. Six inch band of lenticular chert nodules bedded in limestone.
3. Five feet of limestone similar to stratum 1, but with few fossils.
4. One foot band of chert and limestone.
5. Two feet of hard gray limestone with few fossils.
6. Eighteen inches of white oolitic limestone.
7. One foot of gray limestone. From the upper surface of this bed large stylolites, often six inches in length, extend down into the limestone. These stylolites are crowded close together and make a very conspicuous band through the quarry.
8. Three feet of gray limestone with few fossils.
9. Three to six feet to the top of the bank. A somewhat shaly gray limestone with many fossils.

Stratum 1 has been considered as Zone IX, and the fauna collected is as follows:

Orthis dubia Hall.
Athyris planosulcata Phillips.
Derbyia keokuk Hall.
Productus marginicinctus Prout.
Syringothyris sp.
Athyris increassatus Hall.
Spirifer tenuicostatus Hall.
Chonetes illinoisensis Worthen.
Zaphrentis centralis Worthen.
Platyceras sp.
Chetetes sp.
Myalina keokuk Worthen.

Zone X.—This zone is represented by stratum 3 at Station 11, and is separated from the preceding zone by the chert band.

The fauna collected is as follows:

Athyris increassatus Hall.
Productus punctatus Martin.
Spirifer pseudolineata Hall.
Spirifer suborbicularis Hall.
Syringothyris textus Hall.
Productus setigerus Hall.
Terebratula sp.
Conocardium indianense Miller. ?
Aviculopecten magna Swallow.

Zone XI.—The next fossiliferous stratum is the oolite bed. Few fossils were collected from this horizon at Station 11, the only species seen being *Rhynchonella mutata.* On the opposite side of Wilson Creek, however, at Station 10, this oolite bed is nicely exposed and has many fossils. The species collected at this locality are as follows:

Rhynchonella mutata Hall.
Orthis dubia Hall.
Eumetria verneuilana Hall.
Derbyia keokuk Hall.
Platyceras acutirostris Hall.
Conocardium meekanum Hall. ?
Batocrinus sp.
Pleurotomaria sp.

It is interesting to note the similarity between this fauna and that of the Spergen Hill beds in Indiana. Both faunas are made up, to a very great extent, of diminutive forms, most of the species occurring at Springfield being also present at Spergen Hill. In both localities the rock is an oolitic limestone, and the similarity of the faunas is probably due to the

similarity of the environments during deposition. In Indiana these conditions were present at the beginning of the St. Louis period, but in Southwest Missouri this diminutive fauna is followed by a good Keokuk fauna.

Zone XII.—Above the stylolite band at Station 11, the first three feet are nearly barren of fossils, the only species seen being *Orthis dubia.* Above this however, in the somewhat weathered limestone, fossils are very abundant. The species collected are as follows:

Chonetes illinoisensis Worthen.
Derbyia keokuk Hall.
Orthis dubia Hall.
Athyris incrassatus Hall.
Spirifer keokuk Hall.
Spirifer suborbicularis Hall.
Phillipsia bufo Meek and Worthen.
Spiriferina sp.
Productus punctatus Martin.
Productus cora D'Orbigny.
Spirifer tenuicostatus Hall.
Zaphrentis centralis Worthen.

This fauna as a whole is Keokuk. The most interesting species is *Chonetes illinoisensis*, which was very abundant through the lower zones and then disappeared entirely. When it first reappeared it was quite rare, but in the present fauna it takes its place as the most abundant species. Specimens from the lower and upper zones are absolutely alike.

List of Stations.

1. Jones Spring, on Gulf R. R. 4 miles S. E. of Springfield.
2. Railroad cut just west of Station 1.
3. Railroad cut ½ mile N. W. of Station 2.
4. Quarry on Gulf R. R., east of Springfield Car and Foundry Co.
5. Quarry at crossing of Gulf and Frisco railroads.
6. Excavation for gas receiver, corner of Main St. and Wilson Creek, Springfield.
7. Quarry at old brewery, near Gulf R. R. shops.
8. Quarry on east side of Wilson Creek and south of Mt. Vernon road.
9. Quarry on opposite side of creek from Station 8.
10. Ledge of oolitic limestone, ¼ mile south of Station 9.
11. Mackey's quarry, 1½ miles S. W. of Springfield.
12. Quarry on N. Washington Ave., near the large spring.
13. Quarry ¼ mile N. E. from Station 12.
14. Quarry ½ mile north from Station 12.
15. Sink hole in N. W. ¼, N. W. ¼, Sec. 8. T. 28, R. 22.
16. Railroad cut on Boliver R. R. at Ritter's Station.
17. Near Pierson Creek, S. W. ¼, S. W. ¼, Sec. 14. T. 29, R. 21.
18. Quarry at Valley Water Mills on Sac Creek, 4 miles N. E. of Springfield.
19. Quarry at Edward's Spring, near the N. W. corner of Sec. 6, T. 28, R. 21.
20. Ledge along Sac Creek, just north of Station 19.
21. Spout Spring, on Sac Creek N. E. of Springfield.

RANGE OF SPECIES.

ZONES.	Burlington.					Keokuk.						
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Athyris incrassatus Hall	×	×	×	×	×	×	×		×	×		×
lamellosa L'Eveille	×	×	×	×	×	×						
planosulcata Phillips						×			×			
Camarophoria subtrigona Meek and Worthen								×				
Chonetes illinoisensis Worthen	×	×	×	×		×		×	×			×
Derbyia keokuk Hall	×	×		×		×	×	×	×		×	×
Eumetria verneuilana Hall							×				×	
Orthis burlingtonensis Hall	×	×	×	×								
dubia Hall							×	×	×		×	×
swallovi Hall	×	×	×	×	×	×						
Productus burlingtonensis Hall	×	×	×			×						
cora D'Orbigny												×
laevicostus White	×											
marginicinctus Pront									×			
punctatus Martin	×		×	×		×		×		×		×
setigerus Hall			×	×		×	×			×		
Rhynchonella mutata Hall								×			×	
Spirifer biplicatus Hall	×											
forbesi Norwood and Pratten	×	×										
grimesi Hall	×	×	×	×	×	×						
keokuk Hall		?										×
lineata Martin	×	×										
lineatoides Swallow				×								
logani Hall						×	×	×				
marionensis Shumard	×											
neglectus Hall							×					
pseudolineata Hall			×			×	×			×		
suborbicularis Hall	×	×	×	×		×	×	×		×		×
tenuicostatus Hall							×		×			×
sp.		×	×	×								
Strophomena analoga Phillips	×	×										
Syringothyris carteri Hall	×											
plenus Hall		×	×	×								
textus Hall						×				×		
Terebratula burlingtonensis White	×											
sacculus Martin							×	×				
Metoptoma umbella Meek and Worthen			×	×								
Phanerotinus paradoxus Winchell	×											
Platyceras acutirostris Hall											×	
equilatera Hall				×		×						
fisurella Hall						×	×					
quincyense McChesney			×	×								
Pleurotomaria montezuma Worthen		×										
Straparollus latus Hall		×										
Aviculopecten magna Swallow						×				×		
Conocardium indianense Miller ?										×		
meekanum Hall ?											×	
Entolium circulus Shumard	×											

RANGE OF SPECIES.

ZONES.	Burlington.					Keokuk.						
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Myalina keokuk Worthen									×			
Actinocrinus multiradiatus Shumard						×						
verrucosus Hall					×							
Agaricocrinus americanus Roemer					×	×	×					
planoconvexus Hall		×										
Batocrinus biturbinatus Hall							×					
nashvillæ Troost							×					
pyriformis Shumard		?				×						
subtractus White						×						
trochiscus Meek and Worthen						×						
Cyathocrinus iowensis Owen and Shumard						×						
Dichocrinus striatus Owen and Shumard		×	×									
Dorycrinus cornigerus Hall						×						
parvus Shumard					×							
Eretmocrinus originarius Wachsmuth							×					
Eucladocrinus pleurovimineus White			×									
Granatocrinus granulosus Meek and Worthen						×	×					
Pentremites conoideus Hall							×					
Physetocrinus ventricosus Hall					×							
Platycrinus saffordi Troost						×	×					
Synbathocrinus swallovi Hall						×						
Amplexus fragilis White and St. John						×						
Hadrophyllum glans White			×	×								
Palæacis obtusus Meek and Worthen						×						
Syringopora harveyi White		×										
Zaphrentis centralis Worthen		×	×	×		×		×	×			×
varsoviensis Worthen						×						
Phillipsia bufo Meek and Worthen				×		×		×				×

Conclusion.

The facts described in the preceding paper, it is believed, satisfactorily establish the following points.

1. There is a succession of faunas in the limestones about Springfield.

2. The faunas of the lower part of the section may be correlated with the Burlington faunas of Iowa, and those of the upper part with the Keokuk faunas.

3. The whole series of sub-faunas is continuous, and the whole series of rocks should be designated by a single name. The Osage Group* is the earliest name suggested for this series of strata.

* H. S. Williams, 1891. Bull. U. S. Geol. Surv., No. 80, p. 109.

4. In the life-history of several species, including brachiopods, a gasteropod, and a coral, the maximum development of the species, both in size and in numbers, is attained at very nearly the same time.

5. *Spirifer logani* is the genetic successor of *Spirifer grimesi.*

New Haven, Conn., Jan. 11th, 1895.

ART. XIX.—*Distribution of the Echinoderms of Northeastern America;* by A. E. VERRILL. (Brief Contributions to Zoology from the Museum of Yale College, No. LIX.)

[Continued from page 141.]

Family SOLASTERIDÆ Perrier.

SOLASTER ENDECA Forbes.

Asterias endeca Retzius, K. Vet. Akad. Handl., vol. iv, p. 237, 1783; Gmelin, Syst. Nat., p. 3162.

Solaster endeca Forbes, Mem. Wern. Soc., vol. viii, p. 121, 1839; Hist. British Starfishes, p. 109. fig., 1841; Müll. and Trosch., Syst., p. 26; Stimpson, Invert. Grand Manan, p. 14, 1853; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345; A. Agassiz, N. Amer. Starfishes, p. 112, pl. 17, figs. 1–5, 1877; Perrier, Stellerides du Mus., in Arch. Zool. Exper., vol. iv, p. 359, 1875; Duncan and Sladen. Echin. Arctic Sea, p. 40, pl. 3, figs. 5–8, 1881; Danielssen and Koren. Norske Nordhavs-Exp., vol. xi, p. 50, pl. 9, fig. 13, 1884; Sladen, Voy. Challenger, vol. xxx, p. 452, 1889.

B. range, 0 to 150 fath., in the cold areas. Taken at numerous stations, in 25 to 100 fath., from Newfoundland to Cape Cod. Common in the Bay of Fundy from low water to 80 fath., and off Cape Cod, 26 to 50 fath. Taken on all the fishing Banks off Nova Scotia in 40 to 150 fath. It occurs on the coasts of Greenland and Northern Europe. Probably circumpolar.

The dorsal surface is closely covered with small pseudopaxillæ. with finer spinules than in any of the following species.

This species is allied to *S. Stimpsoni* Ver., 1879, from the N. W. coast of America. *S. subarcuatus* Sl., from the Southern Indian Ocean, S. lat. 52° 04′, in 150 fath; and *S. torulatus* Sl., from north of the Kermadec Is., in 250 fath., are also closely related.

SOLASTER SYRTENSIS Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 271, 1894.

B. range, 45 to 101 fath., in the cold areas.

Taken by the U. S. Fish Comm. off Cape Cod (Sta. 264), in 80 fath.; and off Cape Sable, N. S., in 101 fath. (Sta. 85, 86, 1877). Several specimens, received from the Gloucester fishermen, were taken on the fishing Banks from George's to Banquereau, N. S., in 45 to 80 fath.

This species is easily distinguished by the even spinulation of its dorsal surface, the pseudopaxillæ being crowded and larger than in *S. endeca*. The rays are usually nine.

It appears to be allied to *S. paxillatus* Sl., from south of Japan, in 345 fath., and to *S. Stimpsoni* V., 1879.

SOLASTER ABYSSICOLA Verrill.

Solaster abyssicola Verrill, this Journal, vol. xxix, p. 152, 1885; Expl. by the Albatross in 1883, in Ann. Rep. U. S. Fish Comm., p. 541, [39], 1885.

B. range, 843 to 1537 fath. Taken at several stations from N. lat. 39° 05′ 30″ to 35° 45′ 30″.

This species is remarkable for the large number of papulæ, of rather large size, between the dorsal plates; they are longer than the spinules when expanded. The actinal plates bear stellate paxillæ, similar to those of the back. It most frequently has eight rays; sometimes seven or nine.

This appears to be allied to *S. regularis* Sl., from west of Patagonia, in 175 fath.

SOLASTER BENEDICTI Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 273, 1894.

B. range, 841 to 1081 fath. Taken at several stations from N. lat. 40° 53′ 30″ to 35° 45′ 23″, by the U. S. Fish Comm.

Easily distinguished by the rather small and well separated dorsal pseudopaxillæ, with few small papulæ between them; by the actinal plates having small groups, mostly of two to four small spines; and by the small number of the transverse adambulacral spines. It usually has nine rays; sometimes ten.

SOLASTER EARLLII Verrill.

This Journal, vol. xvii. p. 473, 1879; Expl. by the Albatross in 1883, in Ann. Report U. S. Fish Comm., vol. xi, p. 541, pl. 13, fig. 50*b*, pl. 19, figs. 50, 50*a*, 1885.

B. range, 120 to 325 fath., in the cold areas. Taken by the U. S. Fish Comm. at a few stations between N. lat. 44° 28′ 50″ and 40° 04′. It was brought by the Gloucester fishermen from several of the Banks off Nova Scotia and Newfoundland, from N. lat. 45° 25′ to George's Bank; taken mostly in 170 to 300 fath.

Most of the specimens are larger than the original type figured, and have a broader and more tumid disk, with wider and more swollen rays, which are usually nine. The dorsal pseudopaxillæ are rather large, stout, and stellate, giving the back a rather coarsely spinulose appearance. The adambulacral and actinal spines are long and tapered.

This is allied to *S. Dawsoni* Ver. (1879), from the N. W. coast of America, in 8 to 15 fath.

CROSSASTER PAPPOSUS Müll. and Troschel.

Asterias papposa Fabricius, Fauna Grönlandica, p. 369, 1780.

Solaster papposus Forbes, Mem. Wern. Soc., vol. viii, p. 121, 1839; Brit. Starfishes, p. 112, fig., 1841; Stimpson, Invert. Grand Manan, p. 15, 1853; Müll. and Trosch., Syst., p. 26, 1842; Perrier, Stellerides du Mus., p. 94; Danielssen and Koren, op. cit., p. 48, pl. 9, fig. 12, 1884.

Crossaster papposus Müll. and Trosch., Wieg. Arch., vol. iv, part 1, p. 183, 1840; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; A. Agassiz, North Amer. Starfishes, pp. 99, 112, pl. 12, figs. 1–5, 1877; Duncan and Sladen, op. cit., p. 36, pl. 3, figs. 1–4, 1881; Sladen, Voy. Challenger, vol. xxx, p. 444.

B. range, 0 to 179 fath. Taken by the Gloucester fishermen at numerous localities on all the fishing Banks, from off Newfoundland, N. lat. 49° 20′ 30″ to George's, in 40 to 125 fathoms; and by the U. S. Fish. Comm., from N. lat. 46° 58′ to 40° 09′. It is common in the Bay of Fundy, from extreme low-water mark to 60 fathoms on hard bottoms; less common and smaller in Casco Bay and Massachusetts Bay, 10 to 50 fath. It is found in the Arctic Ocean and on the northern coasts of Europe.

A closely related species (*S. penicellatus* Sl.) occurs in the S. Atlantic, S. lat. 37° 25′ 30″ to 46° 43′, in 110 to 140 fath. Another allied form occurs on the N.W. coast of America.

CROSSASTER HELIANTHUS Verrill.

Proc. Nat. Mus., vol. xvii, p. 274, 1894.

B. range, 100 to 150 fath., near George's Bank.

LOPHASTER FURCIFER Verrill.

Solaster furcifer Duben and Koren, K. Vet. Akad. Förhandl., p. 243, pl. 6, figs. 7–10, 1844; Thomson, Depths of the Sea, pp. 119, 456, figs. 14, 75, 1873; Danielssen and Koren, op. cit., p. 47, pl. 8, fig. 12; pl. 9, figs. 9–11, 1884.

Lophaster furcifer Verrill, this Journal, vol. xvi, p. 214, 1878; Duncan and Sladen, op. cit., p. 43, pl. 3, figs. 9–12, 1881; Verrill, Expl. by the Albatross, p. 541, pl. 16, figs. 49, 49ª, 1885; Sladen, Voyage Challenger, vol. xxx, p. 459, 1889.

B. range, 111 to 640 fath. Taken at several stations from N. lat. 47° 40′ to 40° 01′; also in the Gulf of Maine in 150 fath., 1872. It is also European and Arctic (N. lat. 81° 41′).

An allied 5-rayed species (*L. radians* Perrier) occurs in the West Indies.

Another closely related species (*L. stellans* Sl.) occurs off the W. coast of S. America, in 40 to 1325 fath.

Family PTERASTERIDÆ.

PTERASTER PULVILLUS M. Sars.

Pteraster pulvillus Sars, Overs. Norges Echinod., p. 62, pl. 6, figs. 14–16, pls. 7, 8, 1861; Verrill, this Journal, vol. xvi, p. 371, 1878.

B. range, 20 to 111 fath. Rare. N. lat. 46° 50′ to Gulf of Maine, off Isles of Shoals, N. H. Bay of Fundy, 20 fath. Banks off Nova Scotia and Newfoundland. It occurs also off the northern coasts of Europe and in the Arctic Ocean.

PTERASTER MILITARIS Müll. and Trosch.

Asterias militaris Müller, Zool. Dan. Prod., p. 234, 1776; Rathke, Zool. Dan., vol. iv, p. 14, pl. 131, 1806.

Pteraster militaris Müller and Troschel, Syst., Aster., Supl., p. 128, pl. 6, fig. 1, 1842; Stimpson, Invert. Grand Manan, p. 15, 1853; M. Sars, Overs. Norges Echinod., p. 48, pl. 3, figs. 8, 9, pl. 4, figs. 4-6, 1861; Duncan and Sladen, op. cit., p. 46, pl. 3, figs. 13–16. Danielssen and Koren, op. cit., p. 70, pl. 13, figs. 18, 19, 1884; Verrill, Expl. by the Albatross, p. 541, pl. 13, fig. 35, 1885.

B. range, 10 to 200 fath. From 10 to 530 fath. (Sladen). Taken at many stations from N. lat. 47° 29′ to Massachusetts Bay. Common in the Bay of Fundy in 10 to 50 fath. Also European and Arctic.

TEMNASTER HEXACTIS Verrill.

Pteraster (*Temnaster*) *hexactis* Verrill, Proc. Nat. Mus., vol. xvii, p. 175, 1894.

B. range, 57 fath. Only one specimen taken, N. lat. 43° 05′. No allied species is known.

DIPLOPTERASTER MULTIPES Verrill.

Pteraster multipes M. Sars, Vidensk. Selskabs. Förhandl., 1865, p. 200; Fauna Litt. Norvegiæ, p. 65, pl. 8, figs. 1–17, 1877.

Diplopteraster multipes Verrill, this Journal, vol. xx, p. 400, 1880; Ann. Report U. S. Fish Comm., for 1882, vol. x, p. 659, 1884; op. cit., vol. xi, Expl. by the Albatross in 1883, p. 542, pl. 14, fig. 43, 1885.

Retaster? multipes Sl., op. cit., pp. 477, 478, 800, 1889.

B. range, 67 to 640 fath. Most commom between 100 and 300 fathoms. Taken at many stations between N. lat. 44° 26′ and 37° 07′ 50″. Occurs also off the Norwegian coast.

The two following species, described by Mr. Sladen from the southern hemisphere, appear to belong to this genus and to be closely allied to our species:

Diplopteraster verrucosus V. = *Retaster verrucosus* Sl., Magellan Str., 55 fath.

D. peregrinator V. = *Retaster peregrinator* Sl., off Kerguelen I., 127 fath.

These have the ambulacral feet in four rows and the broad, thick, fleshy actinal membrane characteristic of this genus.

LOPHOPTERASTER, gen. nov.

Form and general appearance as in *Pteraster*, from which it differs chiefly in having a very prominent, solid crest or keel-like prominence on the center of each jaw; it forms the inner angle of the jaw, separating the two groups of oral spines in the middle. The latter are otherwise webbed together. Two small, actinal jaw-spines on each side. Actinal radial spines well developed. Adambulacral spines webbed. Supradorsal membrane nearly as in *Pteraster*. Definite, dorsal interradial channels.

LOPHOPTERASTER ABYSSORUM, sp. nov.

Form stellate, with five short rays. Radii 42 and 22^{mm}. Disk large and swollen dorsally, covered with definite, angular areolations, due to the outer circle of paxillary spinules being longer than the others; many of the shorter ones project slightly above the cuticle within the areolæ; the central spinules is scarcely larger than the rest. Muscular fibers feeble, radiating. Papulæ small and rather numerous. In each interradial area there is a furrow, bordered by divergent, webbed groups of spinules; no definite openings are visible in them, except some pores rather larger than usual. The slender, glassy, actinal radial spines, covered with thin membrane, project as a fringe at the margin. Adambulacral spines slender, five to seven, webbed for about half their length, and bordered with web to the tips. Valve of the segmental pores semi-oval, attached by the entire adoral margin and supported by a short, central spinule.

B. range, 2021 fath. Two specimens (8141) from station 2226, in 2021 fathoms, N. lat. 37°, W. long, 71° 54′.

No allied species is known.

Dorsally this species resembles *Pteraster pulvillus*, for which it was mistaken at first.

HYMENASTER MODESTUS Verrill.

Hymenaster modestus Verrill, this Journal, vol. xxix, p. 151, 1885; Proc. Nat. Mus., vol xvii, p. 277, 1894.

B. range, 1098 to 1451 fath. Very rare. Taken at two stations, N. lat. 39° 40′ 05″ and 39° 22′ 20″.

HYMENASTER REGALIS, sp. nov.

Form stellate with five rays. Greater radii, 70^{mm}; lesser, 45^{mm}. Disk somewhat swollen, with the interradial areas sunken; rays broad, somewhat swollen, broadest a little beyond the base, regularly tapered. The entire dorsal surface is covered with long, prominent, sharp spines, which project far beyond the super-dorsal membrane, but are covered with cuticle to the tip; these spines form nine regular, longitudinal rows on each ray; those in the two rows on each side of the rays are united by a web extending about a third of their height. About ten clusters of similar spines surround the central area of the disk, which is covered by five, broad, concave, valve-like structures, which close the central pore. These valves are supported by numerous slender spines, which project along their inner margins, and several stouter spines on the distal margin, all of which are webbed together. Each

dorsal spine is the central spinule arising from a large, elevated paxilla, the other spinules being rudimentary or absent.

Attached to each spine is a group of numerous strong radiating fibers which extend from spine to spine and support the intervening membrane, which rises in a tent-like form at the base of each spine. The spiracles are everywhere numerous and rather large. The actinal interradial areas are covered by a smooth, thick integument, which extends out as a web, between the bases of the arms, and as a border along their sides, to near the end. The radial spines are short and nearly concealed by the membrane. Those about opposite the middle of of the furrow are the longest and reach the margin of the web, but do not project beyond it; but those toward the tips of the rays, where the web is narrow, project beyond its margins; those toward the inner end of the furrow become quite short; but those next the jaws are again somewhat lengthened. The furrows are wide and shallow. The ambulacral feet are very large, arranged in two rows, conical, with a small sucker at the tip. Each adambulacral plate bears three long slender spines of which the two outer are much the longest, they stand in an oblique row, the two inner ones being more aborally placed than the other, and nearly side by side; the innermost is much smaller than either of the others; all are covered and bordered by soft cuticle, which also extends in a soft flap beyond the tip. The segmental pores are very large and conspicuous and covered by a soft membranous valve, irregularly ovate in form, bilobed at the tip, and attached by the end next the furrow, where it is supported by a short, thick, stump-like spine. Each jaw bears a median, solid, short, thick, elevated crest or keel, which projects inward slightly, between the oral spines; a large actinal spine arises on each of its sides, a little nearer the inner than the outer end; another pair of similar, but somewhat smaller, spines arises on each side of the inner end; three much smaller, slender spines arise from the lateral margin of each jaw; these spines are covered with cuticle which projects in long flaps beyond the tips, but does not form a web.

B. range, 1374 fath. A single specimen (No. 15,556) was taken at station 2725, N. lat. 36° 34′, W. long. 73° 48′.

Species of this genus are found in all the oceans at great depths. None of the numerous described species resemble this very much.

Family Echinasteridæ Verrill.

Cribrella pectinata Verrill.
Proc. Nat. Mus., vol. xvii, p. 278, 1894.

B. range, shallow water (about 20 fath.), Bay of Fundy.

CRIBRELLA SANGUINOLENTA Lütken.

Asterias sanguinolenta Müller, Zoöl. Dan. Prod., 2836, 1776.
Asterias oculata Pennant, Brit. Zoöl., vol. iv, p. 61, pl. 30, fig. 56, 1777.
Asterias spongiosa Fabricius, Fauna Grœnl., p. 368, 1780.
Linkia oculata Forbes, Wern. Mem., vol. viii, p. 120, 1839.
Cribella oculata Forbes, British Starfishes, p. 100 (figure), 1841.
Echinaster oculatus Müller and Troschel, Syst. Asterid., p. 24, 1842.
Linkia oculata Stimpson, Invert. of Grand Manan, p. 14, 1853.
Linkia pertusa Stimpson, op. cit., p. 14.
Echinaster sanguinolentus Sars, Fauna Litt. Norveg., i, p. 47, pl. 8, figs. 3–6; Oversigt af Norges Echinodermer, p. 84, 1861.
Cribrella sanguinolenta Lütken, Grœnl. Echinod., p 31, 1859; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; Verrill, Invert. Vineyard Sd., pp. 407, 425, 1873; A. Agassiz, N. Amer. Starfishes, p. 113, pl. 18, 1877.
Cribrella oculata Perrier,* Stellerides, in Arch. Zoöl. Exper., vol. iv, p. 373, 1875; Duncan and Sladen, op. cit., p. 32, pl. 2, figs. 18–21, 1881; Danielssen and Kor., op. cit., p. 34, 1884; Sladen, op. cit., p. 542, 1889.

B. range, 0 to 471 fathoms; off New Jersey in 1350 fathoms, Sladen. Rare below 200 fathoms on our coast. Very abundant north of Cape Cod in 1 to 50 fath., on hard bottoms. Common in the cold area south of Martha's Vineyard, in 10 to 60 fathoms. It is found off Cape Hatteras. Taken at more than 400 stations between N. lat. 47° 29′ and 35° 38′. It enters the eastern part of Long Island Sound. It ranges to Greenland and the Arctic Ocean generally, and to northern Europe.

Allied species are found in all the oceans; about 14 are recognized.

Family PEDICELLASTERIDÆ.

PEDICELLASTER TYPICUS M. Sars.

Oversigt over Norges Echinod., p. 77, pl. 9, figs. 9–17, pl. 10, figs. 1–10, 1861; Verrill, this Journal, vol. xvi, p. 214, 1878; Danielssen and Koren, op. cit., p. 36, 1884; Sladen, Voy. Challenger, pp. 557, 814, 1889.
Pedicellaster palæocrystallus Duncan and Sladen, op. cit., p. 34, pl. 2, figs. 22–26, 1881; Sladen, Voy. Challenger, vol. xxx, pp. 557, 560 (note).

B. range, 79 to 122 fath. From 50 to 620 fath., Sladen. Taken a few times, sparingly, from N. lat. 43° 19′ to 42° 15′ 25″. Also found in the Gulf of St. Lawrence. It ranges to the Arctic Ocean and northern Europe.

Nine or ten species of this genus are recorded from the Atlantic and Antarctic regions, mostly in deep water.

Family ZOROASTERIDÆ Sladen.

ZOROASTER DIOMEDEÆ Verrill.

Zoroaster Diomedeæ Verrill, Brief Cont. No. 55; this Journal, vol. xxviii, p. 217, 1884; Expl. by the Albatross in 1883, p. 540 [38], 1889.
? Zoroaster fulgens (pars) Sladen, Voy. Challenger, vol. xxx, p. 418, plates 66 and 68, 1889.

* I do not consider it justifiable to follow Perrier, Sladen, and others in the revival of the ancient name (*oculatus*) given to this species in 1733 by Linck, who was not a binomial writer. If it be necessary to do so in this case, the same argument would apply to all his other trivial names, and to all his generic terms also. The name of this species would, in that case, stand as *Pentadactylosaster oculatus* Linck.

B. range, 1098 to 1555 fath. Most abundant from 1300 to 1500 fath. In one doubtful case, recorded from 471 fath. (one specimen). Dredged at 16 stations from N. lat. 41° 09′ 40″ to 37° 27′.

Allied species are found at great depths in most seas. *Z. fulgens* Thomson, from the eastern Atlantic, 500 to 1350 fath., and *Z. Ackleyi* Per., from the West Indies, are nearly related to our species if not identical. Mr. Sladen refers specimens dredged by the Challenger off our coast in 1250 to 1350 fath. to *Z. fulgens*. These were probably identical with our species and indicate that the two described forms may be the same. He also records *Z. fulgens* from off Brazil, in 675 fath.

Family Stichasteridæ Perrier.

Neomorphaster forcipatus Verrill.
Proc. Nat. Mus., vol. xvii, p. 269, 1894.

B. range, 852 to 990 fathoms. Three stations off George's Bank and S. of Martha's Vineyard.

The only species allied to this is *N. eustichus* Sladen, from 900 to 1000 fath., off the Azores.

Stichaster albulus Verrill.

Asteracanthion albulus Stimpson, Invert. Grand Manan, p. 14, pl. 1, fig. 5, 1853.

Stichaster albulus Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 351, 1866; Perrier, Arch. Zool. Exper., vol. iv, p. 347, 1875; Duncan and Sladen, op. cit., p. 29, pl. 2, figs. 13–17, 1881; Danielssen and Koren, op. cit., p. 31, pl. 8, figs. 13–15, 1884; Sladen, Voy. Challenger, vol. xxx, p. 432, 1889.

Asteracanthion problema Steenstrup, Vidensk. Medd. nat. Foren., p. 240, 1854; Lütken, Grönl. Echinod., p. 30, 1857.

Stephanasterias albula Verrill, Bulletin Essex Inst., vol. i, p. 5, 1871; Expl. Casco Bay, p. 353, 1874; Check List, 1879; Expl. by the Albatross in 1883, p. 540, 1885.

B. range, 0 to 229 fath.; in one case recorded from 435 fath., off Delaware. Common from low-water mark to 100 fath. in the Bay of Fundy and off the coast of Nova Scotia. Dredged at more than 100 stations between N. lat. 46° 50′ and 35° 12′ 30″. Off Cape Hatteras it is common in 16 to 50 fath. Common S. of Martha's Vineyard in 50 to 150 fath. Its range extends to Greenland, Iceland and other parts of the Arctic Ocean, and the northern coasts of Europe.

Allied species are found in most seas.

This family seems hardly worthy of separation from the next.

Family Asteriidæ.

Asterias Forbesii Verrill.

Asteracanthion Forbesii Desor, Proc. Boston Soc. N. H., vol. iii, p. 67, 1848.

Asterias arenicola Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii, p. 268, 1862; Verrill, ditto, vol. x, p. 339, 1866; Invert. Vineyard Sd., p. 424, 1873.

Asteracanthion berylinus Ag. MSS., A. Agassiz, Embryology of Echinod., in Proc. Amer. Acad., 1863; Embryology of the Starfish, in Agassiz Contributions, vol. v, p. 3; Sea-side Studies, p. 108, figs. 141–145, 1865; N. American Starfishes, p. 94, pl. 9, 1877.

Asterias Forbesii Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 345, 1866; Invert. Vineyard Sd., p. 424, 1873; this Journal, vol. xi. pp. 418, 419, 1876.

Asterias Forbesii and *A. arenicola* Perrier, Arch., Zool. Exper., vol. iv, p. 315, 1875.

B. range, 0 to 27 fath., chiefly in the warm areas. Its normal range extends from Massachusetts Bay to Northern Florida and the northern shores of the Gulf of Mexico, in shallow water; rare and local, in sheltered localities, north of Massachusetts, as at Quahog Bay, east of Portland, Maine, and near the mouth of the Kennebeck River.

Very abundant in Long Island Sound; Buzzard's Bay; Vineyard Sound; and along the shores of Long Island, from low-water to 15 fathoms, especially on oyster beds, where it is very destructive.

ASTERIAS VULGARIS Stimpson, MSS.

Packard, in Canadian Naturalist and Geologist, 1863 (no description); Verrill, Proc. Boston Soc. Nat. Hist, vol. x, p. 347, 1866 (description).

Asterias Stimpsoni (*pars*) Verrill, Proc. Bost. Soc. Nat. Hist., vol. x, p. 349, 1866, Young.

Asteracanthion pallidus Ag. MSS.; A. Agassiz, Embryology, in Proc. Amer. Acad., 1863 (no description); Embryology of the Starfish, in Agassiz' Contributions, vol. v, p. 3.

Asterias vulgaris Verrill, Invert. Vineyard Sd., pp. 490, 424, 1873; this Journal, vol. xi, p. 419, 1876 (revision).

Asterias pallida, *A. vulgaris*, and *A. Fabricii* Perrier, Arch., Zool. Exper., vol. iv, pp. 317–320, 1875.

B. range, 0 to 358 fath; most abundant in 1 to 60 fath. Belongs to the cold areas. Eastern part of Long Island Sound to Labrador, in shallow water; in deep water it ranges southward as far as off Cape Hatteras. Very abundant in Massachusetts Bay, Casco Bay, Bay of Fundy, from above low-water mark to 60 fathoms; common in the deeper parts of Vineyard Sound and off Buzzard's Bay in 6 to 45 fathoms; common S. of Martha's Vineyard in 10 to 50 fathoms, and occasionally in 190 to 358 fath.; off Watch Hill, Rhode Island, 4 to 20 fathoms, common; Faulkner's Island, Connecticut, low-water, rare.

ASTERIAS STELLIONURA Perrier.

Asteracanthion stellionura Perrier, Ann. des Sci. Nat., vol. xii, p. 420, pl. 1, figs. 10*b*, 10*d*, 1869.

Asterias stellionura Perrier, Stellerides, in Arch. Zoöl. Exper., vol. iv, p. 310, 1875; Verrill, this Journal, vol. xvi, p. 214, 1878; Danielssen and Koren, op. cit., p. 14, pl. 4, figs. 1–9, 1884.

B. range, 40 to 300 fathoms; strictly northern. Taken at numerous localities on the Grand Banks, Banks off Nova Scotia, and on George's Bank by the Gloucester fishermen, 40 to 300

fath. Dredged at many stations from N. lat. 44° 56′ to 43° 32′, in 69 to 127 fath. Its range extends to the Arctic Ocean, Iceland, etc.

ASTERIAS ENOPLA, sp. nov.

Rays five, long, rather slender, rounded. Disk small. Radii 7^{mm} and 42^{mm}. Abactinal surface with three regular rows of rather long, tapered, acute spines, standing singly, those of the median row slightly larger than the others; similar spines cover the disk. A prominent double lateral row of similar spines on each side, two divergent spines standing one above the other on each plate. A regular, simple, infero-marginal row of still larger, rather strong, acute spines situated close to the adambulacral series; the latter are much smaller, slender, tapered, acute; they stand mostly two on a plate, but often only one. The infero-lateral spines bear a very large cluster of cruciform pedicellariæ on the outer side; the supero-lateral spines bear a much smaller group on the upper side; the dorsal spines are mostly without pedicellariæ. Very large, ovate, acuminate, rectiform pedicellariæ are scattered between the spines, both above and below; the larger ones are often as broad as the adjacent spines; smaller and more acute ones border the inner edges of the ambulacral furrows. The papulæ are large, and mostly stand singly. The dorsal skeleton-plates are short, thick, and stout.

B. range, 53 to 100 fath. Off Nova Scotia, two specimens.

Allied to *A. Gunneri* Kor. and Dan., of the Arctic Ocean, and to *A. stellionura*, but it has a much firmer dorsal skeleton and much longer and larger dorsal spines than either of those species.

ASTERIAS POLARIS Verrill.

Asteracanthion polaris Müll. and Trosch., Syst. Aster., p. 16, 1842; Lütken, Syst. Overs. Grönlands Echinod., p. 28, 1857; Duncan and Sladen, op. cit., p. 23, pl 2, figs. 4–8, 1881.

Asterias polaris Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 356, 1866; Lütken, Vidensk. Meddel. nat. Forening, p. 28, 1871; Verrill, this Journal, vol. xi, p. 420, 1876; K. J. Bush, Proc. U. S. Nat. Mus., vol. vi, p. 246, 1883.

Asterias polaris and *A. borealis* Perrier, Stell. du Mus., in Arch. Zool. Exper., vol. iv, pp. 322, 323, 1875.

B. range, 0 to 60 fath. George's Bank to Greenland. Common from low-water to 20 fath. at Anticosti I., Gulf of St. Lawrence, and on the Labrador coast. Taken by the Gloucester fishermen on all the Banks, in 20 to 50 fath. Dredged by the U. S. Fish Comm. at several stations, from N. lat. 45° 44′ to 45° 10′, in 36 to 50 fath.

This species almost invariably has six rays. It becomes very large and abundant on the Labrador coast and on the Grand Bank.

ASTERIAS TANNERI Verrill.

Brief Cont. to Zool., No. 47, this Journal, vol. xxx, p. 401, 1880; Explorations by the Albatross in 1883, in Ann. Rep. Com'r. Fish and Fisheries, vol. xi, p. 540, pl. 13, figs. 42, 42ª, 1885.

B. range, 48 to 194 fathoms; in one instance recorded as from 373 fath., off C. Hatteras, perhaps an error. Taken at 35 stations, between N. lat. 40° 08′ and 35° 10′ 40″.

ASTERIAS AUSTERA, sp. nov.

Rays five, rather short and stout, smaller, subacute. The skeleton plates are larger, firmer, and more rigid than in the allied species. Radii 10^{mm} and 35^{mm}. Dorsal surface rather sparsely covered with short, stout, blunt, isolated spines, which do not form regular rows; those along the median area of the rays are a little longer and often stand in an irregular double row; a distinct, regular supero-marginal row of slightly longer, but similar, spines; two infero-marginal rows of still longer and more acute spines, separated by a line of papulæ, placed singly to near the end of the rays, and sometimes with a short row of intervening spines distally. Adambulacral spines small, slender, not very long, scarcely tapered, arranged either one or two to a plate, sometimes alternately, but generally the solitary ones are most numerous. Papulæ stand singly or in small clusters. Cruciform pedicellariæ minute, forming a close wreath around all the dorsal and lateral spines, those of the ventral spines interrupted below. Rectiform pedicellariæ of rather large size, narrow ovate or acute lanceolate in form, are scattered between the dorsal spines; others of large size and less acute occur between the ventral and adambulacral spines; smaller ones lie within the furrows.

B. range, 33 to 35 fath. George's Bank and off Cape Cod.

This species should, perhaps, be referred to *Leptasterias*. The character of its ova is not known.

ASTERIAS BRIAREUS Verrill.

Verrill, Brief Cont. to Zool., No. 50, this Journal, vol. xxiii, p. 220, 1882; Notice of Rem. Maine Fauna, in Ann. Rep. Com'r. of Fish and Fisheries for 1882, p. 659, 1884.

B. range, 78 to 373 fath. Rare. Taken at three stations, from N. lat. 37° 18′ 11″ to 36° 41′ 05″. It is also found in the West Indies.

LEPTASTERIAS COMPTA Verrill.

Asterias compta Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii. p. 270, 1862; Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 340, 1866; Sladen, op. cit., vol. xxx, p. 583, 1889.

Leptasterias compta Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 350, 1866; Mar. Invert. Vineyard Sd., p. 425, 1873; Expl. Casco Bay, in Proc. Amer. Assoc. for 1873, pp. 353, 356, 1874; Check List, p. 14, 1879; Expl. by the Albatross in 1883, p. 540, 1885.

B. range, 10 to 100 fath. Taken at many stations, from N. lat. 45° 29′ to 37° 19′. Large and abundant in the cold

areas S. of Rhode Island and Martha's Vineyard, in 20 to 50 fath. Allied to *L. hyperborea* (D. and Kor.) of arctic Europe.

LEPTASTERIAS TENERA Verrill.

Asterias tenera Stimpson, Proc. Boston Soc. Nat. Hist., vol. viii, p. 269, 1862; Verrill, op. cit., vol. x, p. 349, 1866.

Asterias (*Leptasterias*) *tenera* Verrill, loc. cit., pp. 349, 350.

Leptasterias tenera Verrill, this Journal, vol. vii, p. 504, 1874; Expl. Casco Bay, in Proc. Amer. Assoc. Adv. Sci. for 1873, p. 353, 1874; Check List, p. 14, 1779.

B. range, 10 to 129 fath. Cape Cod to Newfoundland. Common in Massachusetts Bay and the Bay of Fundy, in 10 to 40 fath. This is very closely allied to *L. compta*, of which it may be only a poorly nourished, slender variety. It requires more careful study to determine this question. It is closely allied to the European *L. Mülleri*,—perhaps the same.

LEPTASTERIAS GRŒNLANDICA Verrill.

Asteracanthion Grœnlandicus Lütken, Videns. Meddel. naturh. Forening, 1857, p. 29; Duncan and Sladen, op. cit., p. 27, pl. 2, figs. 9–12, 1881 (*grœnlandicum*).

Asterias Grœnlandica Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 357, 1866.

Leptasterias Grœnlandica Verrill, Check List, p. 14, 1879.

B. range, 5 to 100 fath. Strictly northern. Taken in the Bay of Fundy and Gulf of St. Lawrence, and on the fishing Banks off Nova Scotia. It ranges to the Arctic Ocean (N. lat. 81° 41′).

LEPTASTERIAS HISPIDELLA, sp. nov.

Rays five, rather short and thick, well rounded, tapered. Radii 5^{mm} and 27^{mm}. Abactinal surface covered with very slender, rather long, very sharp spines, placed singly, and forming three pretty regular marginal rows on each side and a rather indistinct median row, with about two more or less distinct rows between the median and supero-lateral; the marginal spines are longest; the infero-marginal spines are close to the adambulacral, and sometimes stand two on a plate proximally; a few single papulæ usually alternate with them proximally. Adambulacral spines long and slender, divergent, mostly alternately one and two to a plate. Rectiform or major pedicellariæ of actinal surface few, rather large, long-ovate or lanceolate, rather acute, with sharp, curved denticles at the tip; smaller ones border the furrows, within; crossed pedicellariæ form small clusters on the dorsal spines and larger ones on the laterals. The dorsal plates are rather slender, with large interspaces, in which the papulæ stand singly, or two or three together. Madreporite small, with few coarse short gyri.

B. range, 50 fath. N. lat. 45° 14′ 30″, stat. 2494, two specimens.

Allied to *L. littoralis*, but has much longer and very acute spines, which are less numerous.

LEPTASTERIAS LITTORALIS Verrill.

Asteracanthion littoralis Stimpson, Invert. Grand Manan, p. 14, 1853.
Asterias littoralis Verrill, Proc. Boston Soc. Nat. Hist., vol. x, p. 349, 1866; Perrier, Stellerides, in Arch. Zool. Exper., iv, p. 315, 1875; Verrill, Expl. Casco Bay, p. 364, 1874.
Leptasterias littoralis Verrill, Check List Marine Invert., p. 14, 1879; K. J. Bush, Moll. and Echinod. Labrador, in Proc. U. S. Nat. Mus., vol. vi, p. 246, 1883.

B. range, 0 to 23 fath. Casco Bay, Me., to Cumberland Gulf. Eastport, Me., at low-water mark among rocks, locally abundant. Also found on the coast of Nova Scotia and in the Gulf of St. Lawrence. This is very closely allied to *L. Grönlandica*.

This, like the other species of *Leptasterias*, carries its large ova and young attached in large clusters around the mouth. It breeds early in the season, April and May, at Eastport, Me.

In addition to the five species of *Leptasterias* here named, there are other forms on our northern coast that may be distinct, but need much study. Some of these have hitherto been referred to *L. Mülleri* and to *L. Stimpsoni* V., 1866. The latter originally included, in part, young of *Asterias vulgaris*, but the description was largely based on a *Leptasterias* that is near *L. hyperborea* (Dan. and Kor.) and probably distinct from those here recorded.

HYDRASTERIAS OPHIDION Sladen.

Asterias (Hydrasterias) ophidion Sladen, Voyage of the Challenger, vol. xxx, p. 581, pl. 99, figs. 3 and 4; pl. 103, figs. 3 and 4, 1889.
Hydrasterias ophidion Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 279, 1894.

B. range, 1250 to 1742 fath. One specimen was dredged in N. lat. 40° 34′ 18″, W. long. 66° 09′, 1742 fath. It was taken by the Challenger in N. lat. 42° 08′, off Halifax, in 1250 fath.

Family BRISINGIDÆ Sars.

ODINIA AMERICANA Verrill.

Brisinga Americana Verrill, this Journal, vol. xix, p. 139, 1880; Expl. by the Albatross in 1883, in Rep. Com'r. Fish and Fisheries, xi, p. 636, pl. 17, fig. 52, 1885.
Freyella Americana Sladen, Voyage of the Challenger, vol. xxx, pp. 616, 617, 834, 1889.
Odinia Americana Verrill, Proc. Nat. Mus., vol. xvii, p. 279, 1894.

B. range, 175 to 400 fath. Two specimens were taken by the Gloucester fishermen on Banquereau, off Nova Scotia, one at N. lat. 44° 12′, W. long. 58° 37′, clinging to *Paragorgia arborea*.

Both of our specimens had 20 (detached) arms. It grows to great size.

BRISINGA COSTATA Verrill.

Brisinga costata Verrill, this Journal, vol. xxviii, p. 382, 1884; Proc. U. S. Nat. Mus., vol. xvii, p. 280, 1894.

B. range, 828 to 2021 fath. Taken at several stations from N. lat. 41° 28′ to 35° 45′ 23″.

Species of *Brisinga* and *Freyella* are found at great depths in all the oceans.

BRISINGA MULTICOSTATA Verrill.

Brisinga multicostata Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 280, 1894.

B. range, 1137 to 1742 fath. Dredged by the U. S. Fish Comm. at three stations from N. lat. 40° 34′ 18″ to 39° 35′.

BRISINGA VERTICILLATA Sladen.

Brisinga verticillata Sladen. Voyage of the Challenger, vol. xxx. p. 604, pl. 109, figs. 9–11, 1889; Verrill, Proc. Nat. Mus., vol. xvii, p. 283, 1894.

B. range, 906 to 1423 fath. Dredged at 9 stations from N. lat. 41° 13′ to 36° 34′. Taken by the Challenger at N. lat. 40° 17′, off New Jersey, in 1350 fath.

FREYELLA ELEGANS Sladen.

Brisinga elegans Verrill, this Journal, vol. xxviii, p. 382, 1884.

Freyella bracteata Sladen, Voyage of the Challenger, vol. xxx, p. 629, pl. 114; figs. 1–4, 1889.

Freyella elegans Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 283, 1894.

B. range, 1060 to 2021 fath. Taken at 18 stations by the U. S. Fish Comm. from N. lat. 41° 43′ to 36° 34′. Dredged by the Challenger at three stations from N. lat. 42° 08′ to 40° 17′, in 1250 to 1350 fath., off the American coast.

FREYELLA MICROSPINA Verrill.

Proc. U. S. Nat. Mus., vol. xvii, p. 286, 1894.

B. range, 1054 to 1060 fath. Taken twice by the U. S. Fish Comm., at N. lat. 39° 46′ 30″ and 39° 43′ 30″.

FREYELLA ASPERA Verrill.

Freyella aspera Verrill, Proc. U. S. Nat. Mus., vol. xvii, p. 285, 1894.

B. range, 1917 fath. One specimen was dredged at N. lat. 37° 59′ 20″, off Chesapeake Bay.

Fragments of a fourth species of *Freyella* were dredged at Sta. 2077, N. lat. 41° 09, in 1255 fath.

Bathymetrical Distribution of the Families of Asterioidea, in this Region.

[The numerals refer to the number of species found in each zone of depth.*]

Fathoms.	0-50.	50-100.	100-500.	500-1000.	1000-2000.	2000-2600.	Total species.
Archasteridæ	0	2	4	6	6	2	8
Porcellanasteridæ	1	1	1	2	1	0	2
Astropectinidæ	5	4	4	3	2	0	8
Goniasteridæ	2	5	5	3	2	1	8
Gymnasteridæ	0	3	4	2	0	1	5
Asterinidæ	0	1	1	0	0	0	2
Solasteridæ	3	5	5	3	2	0	8
Pterasteridæ	2	4	2	1	2	1	7
Echinasteridæ	2	1	1	0	0	0	2
Pedicellasteridæ	0	1	1	1	0	0	1
Zoroasteridæ	0	0	0	1	1	0	1
Stichasteridæ	1	1	1	1	0	0	2
Asteriidæ	11	9	5	0	1	0	15
Brisingidæ	0	0	1	2	6	2	7
No. of species	27	37	35	25	23	7	76

* The slight differences in the numbers here given, as compared with the list on page 128, is due to the discovery of a few additional species after the first part of this paper was printed.

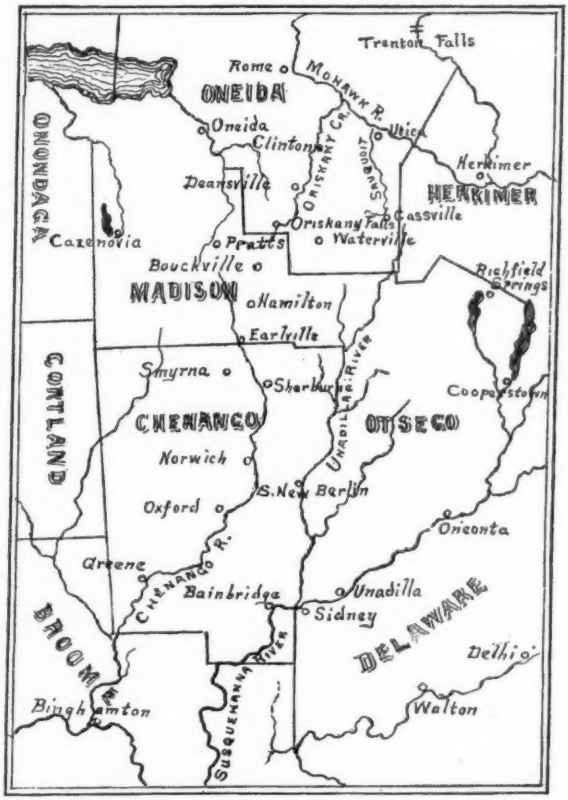
Art. XX.—*Drift Bowlders between the Mohawk and Susquehanna Rivers;* by Albert P. Brigham.

The district traversed in my investigations extends from Utica on the Mohawk River, south-south-westward to the confluence of the Chenango and Susquehanna Rivers at Binghamton, a distance of 95 miles. It is approximately the line of the Oriskany and Chenango valleys; or of the New York, Ontario and Western Railway from Utica to Oxford and the Delaware, Lackawanna and Western Railway from Utica to Binghamton. The main valleys, valley slopes and summits of the hill ranges were seen continuously for the first 40 miles from the Mohawk, and over a breadth of from 10 to 20 miles. Farther south a series of points was selected, with observations at all altitudes.

Topography.—The district belongs to the plateau region of central and southern New York, dropping down to the level of the Mohawk valley on the north. The Mohawk-Susquehanna divide averages 20 miles distance from the Mohawk River. From this divide extend northward and southward the valleys and hill ranges which are characteristic of central and western New York. The northern slope is drained by the Sauquoit, Oriskany, and Oneida Creeks; the southern slope carries the Chenango, Unadilla and Susquehanna Rivers. The divides in the region considered are: Cassville, altitude 1215 feet; Waterville, 1238 feet; Bouckville, 1147 feet; Pratts, altitude not known, but somewhat greater than that of Bouckville. At Rome we have 445 feet and at Utica, 410 feet. South of the divide the record is: Hamilton, 1111 feet; Norwich, 1001 feet; Binghamton, D. and L. and W. R. R., 846 feet; Binghamton, Susquehanna River 814 feet. The hills rise from 500 to 700 feet above the adjacent valleys, culminating in Tassel Hill, Paris, Oneida County, 1948 feet. Comparing the railway levels at Utica, and Binghamton with the summit at Bouckville, it will be seen that we descend northward 737 feet in 24 miles, and southward 301 feet in 71 miles, making the average northern slope of the valley bottoms 30·71 feet per mile; average southern slope 4·24 feet per mile. The distances are taken from the railroads. Air line measurement would slightly change the figures. From a limited number of aneroid determinations it is thought that the altitude of the hill ranges is even more sustained going southward, than that of the valley bottoms. The writer hopes to discuss the meaning of these facts in a later paper on the topographic history of the Chenango Valley region. Four sections of the moraine described by Professor Chamberlin,* lie within the field of this

* Terminal Moraine, etc., 3d Ann. Rep. U. S. G. S., p. 360.

paper; viz: from Sauquoit to Cassville; about Waterville; from Deansville to Solsville, and from Munnsville to Pratts. These all stretch up the north flowing streams to about the position of the divides in the respective valleys. Extensive valley trains appear southward, with recurrent terraces and kames throughout the Chenango valley.



The Geological Formations.—The conditions are excellent for the determination of linear (southward) and vertical distribution of bowlders, from the manner in which narrow lines of outcrop cross the track of the ice. It is evident that we have here no such conditions for the study of lateral distribution as are afforded by Iron Hill in Rhode Island,* and the

*N. S. Shaler, Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11.

quartzite knobs of Wisconsin.* The pre-Paleozoic rocks referred to in this paper are for convenience classed as Archæan. The nearest outcrops, except by faulting at Little Falls, are at the southwestern base of the Adirondacks, 30 miles from Utica. The Cambrian is represented by the Potsdam sandstone of St. Lawrence, Jefferson and Lewis Counties. The Ordovician consists of Calciferous, Trenton, Utica and Hudson River, outcropping in a nearly N. W. by S. E. direction, only the Utica and Hudson River appearing as far south as the Mohawk valley, in this region. The Silurian beds, Oneida-Medina, Clinton, Niagara, Salina and Lower Helderberg, cross our field in nearly east and west bands, and as a whole extend south to Oriskany Falls. It is evident from the sharp descent from the divide to the Mohawk, that the outcrops must be narrow and that the bottom ice was pushed up across their bevelled edges. The Devonian column begins with the Oriskany sandstone, Corniferous and Marcellus about Oriskany Falls and Waterville and passes to a broad band of Hamilton extending southward to Smyrna, where it is succeeded by the Upper Devonian members, continuing to Binghamton.

Of the above masses, the Calciferous and Trenton have not been recognized within the field studied, though they doubtless exist in small fragments. The older and more distant Potsdam forms a quite constant element in our drift, being composed, both in its cement and constituent grains, of nearly pure quartz. But without microscopic examination it is in danger of being confused with certain Medina and Clinton fragments which resemble it in color.† The Utica, Salina and Marcellus are too soft for massive transportation beyond short distances. The sandstones of the Hudson River, and to a large extent of the Clinton, have not afforded ready identification, being largely without fossils and weathering to a non-committal brown.‡ The Niagara is very thin in Oneida County, though a certain peculiar structure is very characteristic,§ and four or five pebbles have been found from 20 to 50 miles from its outcrop. The main reliance has been upon the Archæan, Oneida, Lower Helderberg, Oriskany Sandstone and Corniferous. A separate discussion of these terranes and their bowlders will follow. Sandstones of the Hamilton and several of the higher

* Ira M. Buell, Trans. Wis. Acad. Sci., ix, pp. 255–274; Cf. T. C. Chamberlin, Jour. Geol., i, pp. 255–267.

† Since writing the above, Professor C. H. Smyth, Jr. has kindly subjected to microscopic examination a representative fragment from my specimens, finding it to be a thoroughly indurated quartzite, not likely to be matched in any of our lower Paleozoic horizons save the Potsdam.

‡ On limitation of identification, see, The Drift—its Characteristics and Relationships, R. D. Salisbury, Jour. Geol., vol. ii, Oct.–Nov., 1894, p. 717.

§ Vanuxem, Geol. 3d. Dist. N. Y., pp. 92, 93.

members weather to monotonous browns and grays and would need careful attention to their fossil contents for trustworthy identification.

The dip of these beds, in connection with the dissection of the region into north and south trenches and ridges, is an essential fact in the study of vertical distribution, or of the plucking action of the ice. The several terranes first appear, as one goes southward, in northward loops on the hills, and disappear as southward loops in the valleys. Vanuxem cites a measurement for the Corniferous near Waterville, as 27 feet per mile S. W. The Oriskany sandstone at Oriskany Falls dips 47 feet per mile. 40 to 50 feet per mile, S. S. W. is probably a safe general statement for the region.

General Movement of the Ice.—Striæ observed at several localities indicate that the main movement of the glacial current was about S. 20° W. This conclusion is based upon comparison and averaging of movements at the higher altitudes, and where local topography would not be likely to modify direction. The trend may have been largely influenced by the Adirondacks as a local center of glaciation. If this be true, a S. S. W. flow along the Oriskany-Chenango axis is radial and would be expected. The Hudson River and Oneida bowlders of our field may thus have been plucked from the vicinity of Utica and Rome, although some were doubtless brought in by cross currents from more easterly and westerly points.

Archæan Bowlders.—These fragments of the drift are in the usual lithological variety. No consideration of them relative to their sources, can be had, until their Adirondack and more northerly localities shall have been studied in detail.* A profusion of large Archæan masses is found in northern Oneida County, over the Paleozoic terranes which lie within a few miles of the crystalline areas. For some miles south of the Mohawk, pieces having diameters of four feet are tolerably frequent. South of the divide such fragments are rare. A few comparisons from counts and estimates made in the field, will give the best notion of the facts. Approaching Oriskany Falls from Clinton, on the summit of the range to the westward, six Archæan pieces were observed having axes of four to six feet. These and many smaller ones were seen in increasing numbers on nearing the line of the moraine, which appears in its full strength in the valley at the above village. The valley moraine itself however, consists of kames, which are nearly free from large bowlders. Thirty feet of stone wall in the town of Madison, showing average complexion of bowlders of the adjacent field, give the following result.

* For notes on such comparative study, see G. F. Wright on the Glacial Boundary, Bull. 58, U. S. G. S., pp. 50–52.

Archæan	12
Oriskany sandstone	17
Corniferous	2
Doubtful	1
Hamilton (subjacent)	28
	60

The altitude here is about 1200 feet, or 100 feet above the valley. In eastern Madison, altitude about 1600 feet, extensive heaps are composed wholly of pieces but few inches in size, and at least 99 per cent are from the local Hamilton. This freedom from outside material, with limited exceptions, is characteristic of the higher altitudes of the whole region. A similar estimate in Hamilton, choosing all fragments in a large heap, above one foot diameter, gave:

Archæan	50
Oriskany sandstone	17
Corniferous	2

Oneida and Medina were present but all smaller, likewise the Hamilton, while the larger Oriskanys from the same field, as was learned, had been buried. The cases cited represent more than the average prevalence of the Archæan in number, while in mass, the Oriskany would outrank the Archæan by many hundred per cent.

In the town of Eaton, near Hamilton, one northern piece, well-rounded, measured $9\times7\frac{1}{3}\times6\frac{3}{4}$ feet. This is the largest Archæan bowlder observed by the writer south of the Mohawk River. In 90 miles traversed in the towns of Madison, Hamilton, Eaton and Lebanon, less than a dozen Archæan masses were observed having average diameters of four feet or more. From Earlville to Smyrna no Archæan was seen above $2\times2\frac{1}{2}$ feet. At Smyrna, there is a morainic accumulation of considerable extent. A 60-foot section is exposed showing discordant beds of sand and coarse gravel, with 6 to 12 feet of till containing coarse, angular local material, at the top. 100 pieces from a heap rejected in procuring gravel, ranging from the size of one's fist to five or six inches, gave the following count:

Oneida	2
Clinton	3
Doubtful, perhaps Hudson River or Clinton	10
Doubtful, probably Potsdam and Medina	8
Helderberg limestones	26
Hamilton (subjacent)	51
	100

No Archæans appear in the count. They were rare in the section. Only one seen attained a diameter of one foot. About Norwich and South New Berlin Archæans even of one foot diameter are few. Two, measuring 1½ and 2 feet respectively, were the largest seen. A three foot piece, probably Archæan, was reported to me from near South New Berlin. This, however, had been broken up and removed. At Oxford the kames and terraces, rising 100 feet from the valley bottoms, contain the usual proportion of Archæan pebbles. Farther up, near the quarries of the F. G. Clarke Bluestone Company, heaps and walls containing many hundred cords of cobbles and bowlderets, do not show above one-thousandth part of material older than the Hamilton, that is, of fragments carried 40 miles or more.

The same dearth of distant material is evident on all the hill-slopes about Unadilla and Bainbridge on the Susquehanna, and Greene on the Chenango. At the last named place 1½ miles of fence wall above the 100 foot level, were observed without detecting a single Archæan fragment. At Binghamton, Archæan was found to the height of about 600 feet on the slopes south of the Susquehanna, but no pieces were above a few inches in diameter.

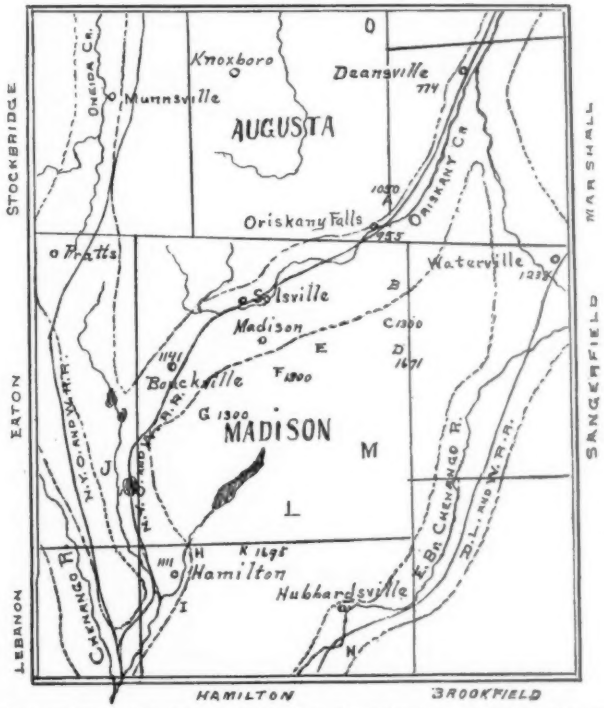
These facts regarding distribution in southern New York are fully in harmony with the facts reported from the adjacent part of Pennsylvania.*

Oneida Conglomerate.—This is a mass 30 to 40 feet thick in the hills two miles south of Utica, thickening somewhat to the westward.† Some layers are mainly composed of rounded quartz pebbles, while others consist of coarse sand. The altitude of the ledge is about 1000 feet near Utica, but drops with the S. W. dip to 620 feet one mile north of Clinton. The conglomerate is one of the most persistent members of the bowlder drift in central and southern New York, though the fragments are rarely numerous, or large. The exception to the latter statement is found within a few miles of the outcrop, as on the northern slope of Paris Hill, where slabs of 4 to 6 feet in length and breadth are not uncommon. In southern Oneida and Madison Counties, any large heap or wall is quite sure to yield small samples, usually not above eight inches in diameter. Only about a dozen were noted, after passing 10 miles from the outcrops, having cubic contents of more than one foot each. One 15-inch Oneida was found at Oxford. Pebbles and small cobbles occur at Binghamton. The falling off in size is much more gradual than in the case of

* See H. C. Lewis and G. F. Wright, 2d Geol. Surv. Pa., Rep. Z, p. 13.

† Reckoned 100 feet thick in generalized central N. Y. section, see C. S. Prosser, Bull. G. S. A., vol. iv, p. 110.

the Oriskany sandstones. These bowlders occur at all altitudes and some have been elevated considerably within moderate distances. The Oneida fragments, at their greatest height in northeastern Madison, have been lifted 600 feet in 14 miles, if we consider them to have come from the highest point in the outcrop. It is more probable that they came from a locality which would require an elevation of 800 feet in 10 miles.



Scale 4 miles to the inch. Dotted line gives the base of main valley walls. Divides at Waterville, Bouckville and Pratts. Oriskany and Helderberg ledges at A. Altitudes of L and M approximate those of D and K.

The bowlderets are commonly more rounded to the southward, though to this there are notable exceptions, perhaps due to splitting in transit.* It was hoped that Oneida fragments north and south of the moraine would afford interesting comparisons as to amount of discoloration and disintegration since the time of deposit. No such result was realized. It is thought

* See N. S. Shaler, Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11, p. 199.

that the variable amount of iron pyrites in the Oneida beds, occasioned the breaking up, or discoloration of some pieces, while others, shaped and deposited at an earlier date, show no signs of change.*

Lower Helderberg.—The limestones are deeply cut by the several valleys at about the position of the moraine belt in each, though not in all cases does the terrane outcrop above the glacial debris, except farther to the north on the hill sides and summits. At Oriskany Falls, 120 feet of these beds are exposed on the west side of the valley, in quarries and natural ledges. 40 feet are massive beds, the rest thin, two to six inches in thickness. The limestone is found not infrequently in slabs and rounded masses up to four feet in breadth or diameter. This is true for only six to eight miles from the outcrop; and it is only for this distance that the limestone occurs at high levels. From Hamilton southward, the fragments are small and almost confined to the gravel trains, terraces and kames of the valleys, rarely occurring above 100 feet from the valley bottoms. The possible causes of this distribution will receive further inquiry after an account of the Oriskany sandstone has been given.

Oriskany Sandstone.—The outcrop, from which the New York geologists named this terrane, is found one half mile north of Oriskany Falls, near the town line of Augusta and Marshall, Oneida County. It appears in a continuous ledge, three fourths of a mile long and 125 feet above the Oriskany Creek, the valley wall rising still 400 feet to the westward. Below it lie 120 feet of Lower Helderberg, and above are 50 feet or more of Corniferous. The hill range is capped with Marcellus and Hamilton. The general trend of the ledge is S. 23° W. The sandstone stands out to its full thickness, 12 feet at the north, thinning to 7 or 8 feet at the south, and dipping southward about 47 feet per mile. Below the sandstone on the valley side, is a broad shelf of Lower Helderberg. The sandstone forms a shelf about 5 rods wide, quite bare except where disintegration has taken place, making a slight cover of soil and vegetation. The rock is a coarse grained, grayish white sandstone, weathering to yellowish brown, with certain zones full of pockets from which the characteristic fossils have disappeared by solution. There are two sets of joints, S. 38°–48° E. and S. 33°–38° W. The joint blocks average 10 to 20 feet in breadth and length, and are often set off, from a few inches to several feet. There is no distinct bedding plane except at the top and bottom of the mass. The passage from the limestone below, and to the limestone above, is sharp, and the

* Suggested to the writer by Professor C. H. Smyth, Jr.

abundant springs issuing on these planes suggest the setting off of the blocks by freezing. But some lie in positions in which only glacial plucking could have placed them.

The shelf of Lower Helderberg, varying from 40 to 80 rods in width and sloping gently to the eastward, has been swept clear of the overlying Oriskany. Evidently the power to pluck ceased more abruptly than the power to transport. But the outmost blocks of the ledge were considerably pared off by grinding action after their neighbors had been carried away. The general movement of the ice was slightly off the ledge to the eastward. The lower ice, which accomplished the plucking, may have swerved to the east locally on this rather steep valley wall, thus increasing the otherwise slight angle between the line of movement and the line of the ledge. Doubtless by weathering along the joint planes, and by solution of the upper surface of the subjacent limestone, as seen under the present ledge, the blocks had been loosened and plucking thus facilitated. Even with this assistance it is puzzling to understand how blocks of some scores of tons weight could be handled, with so little purchase as seems to have been possible.*

The Oriskany valley runs N. 60° E. from the divide to Oriskany Falls, and thence N. N. E. toward the Mohawk. We have here ideal conditions for seeing how ice behaves in crossing a valley diagonally. Our best data are afforded by the transport of large blocks from the above described ledge. The striæ so far as found, and certain glacial flutings on the hills, support the evidence furnished by the travelled blocks. These bowlders were noted by Vanuxem:†

"The Oriskany sandstone first appears out of place and at a higher level in Grout's quarry, amongst the drift, or alluvion on the top of the Onondaga limestone, the thickness of the Cauda-galli Grit and Onondaga Limestone being the difference of its original position and the top of the quarry. The sandstone showed characters of a local origin. The same sandstone is found in great abundance and immense blocks, scattered over the hills in the towns of Madison, Eaton, Hamilton and Lebanon, being more numerous toward the valley of the Chenango canal. They appear on the side-hills, but few having been noticed toward the middle of the valleys. All the blocks there seen were the counterpart of the mass at Oriskany Falls, being readily recognized from local differences in the rock, prevailing at all its points of outcrop." At page 127, Vanuxem speaks again of the frequency of the bowlders in the towns named and adds,—"In smaller masses it has been

* See however T. C. Chamberlin, Rock Scorings of the great Ice Invasions, 7th Ann. Rep. U. S. G. S., p. 193.

† Geol. 3d Distr., N. Y., pp. 127, 222–223.

found from forty to fifty miles south of that line. The great facility with which this rock is recognized, its character so peculiar, contrasting so strongly with all the rocks of New York, its layers so thick at Oriskany Falls, make it a useful rock in investigating the history of the ancient flows of water in that section of the country."*

Going south from the ledge, diagonally across the valley, the southeast valley wall is reached at a distance of two miles. The summit of the range (D. map. p. 219) is three-fourths of a mile further and 600 feet above the ledge. The kame deposits of the moraine are here at least a mile wide, banked against the southeast side. They are transversely cut by a small valley heading near the southeast wall of the main valley. This depression in the moraine was doubtless kept open by a small ice tongue and near its head, but still on the moraine, is a profuse assemblage of large Oriskany bowlders (at B), probably the last of the train to come to rest. The hill-slopes rising directly above the moraine (C) are strewn with the same large fragments. The larger masses and by far the greater number lie on the lower 200 feet of the hillside, at an average altitude of 1300 feet, continuously for several miles to the southwest, (C E F G). In good numbers and up to a diameter of four feet, they rise to the top and are occasionally carried over the summit and through gaps in the range, to the further slopes of another valley which lies several miles to the southeast, about Hubbardsville (N).

At several points on the lower hill-slope referred to, 100 to 150 bowlders ranging from 2 to 7 feet in diameter can be counted upon a single acre. Three miles from the ledge (E) is found an Oriskany block measuring $19 \times 12 \times 8$ feet. Its altitude is 1416 feet. On the slope 150 feet above Madison village (F) on a plot of three to four acres, 86 Oriskany masses were counted, whose dimensions range from 6 to 15 feet. Of these about 15 have lengths and breadths of 10 and 12 feet. All would probably average six foot cubes. Many smaller bowlders, not included in the count, range from five feet downward. Six four foot limestone slabs and one Archæan of like size, were found in this field; but the Oriskanys had been sorted and grouped to a surprising degree. The valley from Oriskany Falls to Pecksport has a bearing of S. 60° W., or at least 40° more westerly than the general ice movement. The hillsides on the northwest of this section of the valley are free from Oriskany bowlders. In the general southward movement

* For other early discussions of New York bowlders see James Hall, Geol. 4th Distr., pp. 332–341, and W. W. Mather, Geol. 1st Distr., pp. 163–197. The latter adds a review of bowlders in New England, the Western States and foreign countries, with numerous references to the earlier literature.

the bowlders were swept diagonally across the valley, a moderate number were carried to, or over the summit of the range, but by far the greater number and almost all the larger fragments were swerved from 0° to 28° westward by the valley wall and caught on the lower slopes. It is a good illustration of the law stated for such cases by Professor Chamberlin.* In further harmony with the passage cited, it is to be noted that the Oriskany valley is neither so broad and shallow as to fail of diversion of the basal currents, nor so narrow and deep as to cause a decided cross current. There can be little doubt that the bowlders in question were moved while the ice was deep and its action vigorous, rather than by an ice tongue at a later and decadent stage.

Near Hamilton the valley bends toward the east and hence the Oriskany bowlders begin to appear on the western slopes. East of Hamilton near the base of the hill, an Oriskany block measures 21×12×10 feet. On the campus of Colgate University, eleven miles from the ledge, the bowlders are abundant, the largest measuring 15⅜×12×10 feet. From Hamilton to Earlville, masses with dimensions of 6 to 8 feet are not uncommon. From Earlville to Smyrna the number is much smaller and but three or four were seen having a diameter of four feet. Near Norwich the track of the ice was crossed for 10 miles. But two Oriskany pieces were seen, each about one foot in diameter, on the lower hill-slope, one mile southwest of Norwich. The last Oriskany fragment recognized, was an 8 inch piece in the valley 1½ miles north of Oxford, or 40 miles from the nearest outcrop.

Vertical distribution.—Oriskany material is infrequent in the kames and gravel trains of the valleys, which, being of somewhat later date, may have buried such of the Oriskany blocks as rested in the valleys. The greatest abundance is on the lower slopes facing the approach of the ice, with moderate carriage to the summits, dropping off to the lower levels, however, as we go southward. When we turn to the question of amount of glacial elevation, it must be noted that Oriskany bowlders occur on the hill range north of the ledge for five miles (to O). Portions of the Oriskany terrane were swept from the summit, whose floor is now of lower Helderberg limestone. Taking into account the dip and comparing the highest northern extension of the preglacial ledge with the greatest height attained by the bowlders in Madison, we find that 248 feet in 8 miles gives the largest rate of ascent which the facts compel us to accept. Several considerations make it probable that the most important assemblage of blocks (at C E F G) was derived from the ledge now seen at Oriskany

* Rock Scorings of the Great Ice Invasions, 7th Ann. Rep. U. S. G. S., pp. 197–200.

Falls. This would give them an average elevation of 250 feet in an average distance of 4½ miles. The single mass before noted (E) would thus have been raised 366 feet in 3½ miles. Upham notes the uplifting of Niagara bowlders to a height of 100 to 200 feet within three or four miles.* C. H. Hitchcock reports the lifting of bowlders 4,000 feet in the White Mountains within moderate distances.†

As already suggested, the east and west extension of the central New York terranes vitiates conclusions as to lateral distribution, or "fanning out" such as has been described by Professor Shaler in Rhode Island and Massachusetts. The Oriskany sandstone is to a considerable extent exceptional, however. In the passage above cited, Vanuxem alludes to local differences and recognizes the Oriskany drift as from Oriskany Falls. For the only outcrop in the next valley to the eastward he notes the presence of a distinctive character. At Munnsville, 6 miles W. N. W. the Oriskany is not present, the two limestones being continuous, and the bowlders are nearly absent from Munnsville to Pecksport. If the Oriskany exists in the valley at all it is a thin wedge south of Pratts, carried by the dip beneath the valley filling. At Morrisville, 10 miles W. S. W., a deep boring apparently found no trace of Oriskany, except quartz grains in the limestone.‡ The ledge at Oriskany Falls thins 4 to 5 feet southward in three-quarters of a mile. The indications are that it thinned northward also. It is a shore formation, which we should expect to find variable within short distances. We probably have a thin lens of sediment, whose maximum thickness is at the present exposed ledge, and the southward bowlders are very surely to be connected with it. In the adjacent valleys, east and west, the Oriskany bowlders, with slight exception, do not occur, or are found so far southward that they can have come across from the Oriskany valley.

The fragments fan out to a width of six miles in a distance of eight miles.§ This cannot, however, be taken as a measure of normal dispersion on a plane surface, for the diagonally disposed valley has widened the train rapidly to the westward.

The Oriskany bowlders were observed with a view to ascertaining the comparative amount of disintegration at the ledge and southward. There has been appreciable loss from the sur-

* Eskers, near Rochester, N. Y., Proc. Roch. Acad. Sci., vol. ii, p. 196, and Bull. G. S. A., vol. v, p. 76.

† Bull. G. S. A., vol. v, p. 37. See also this Journal, III, vol. xxviii, p. 233; Ibid., vol. v, pp. 218, 219. T. C. Chamberlin, Jour. Geol., vol. i, pp. 50–51.

‡ C. S. Prosser, "The Thickness of the Devonian and Silurian Rocks of Central N. Y.," Bull. G. S. A., vol. iv, p. 96.

§ Cf. "Bowlder Train from Iron Hill," Bull. Mus. Comp. Zool., vol. xvi, No. 11, pp. 196–202.

faces only upon relatively flat-topped masses, where water and frosts would act effectively, and along fossil zones, where a retreat of three to six inches from the general surface is not uncommon. On the whole it is thought that the surfaces at the ledge average slightly fresher than those to the southward. On the other hand the impression given is, that all the Oriskany masses belong to the same general movement, and that movement a late one. No buried specimens of large Oriskany bowlders have been found. They have the appearance of being left behind, upon the surface of the hills, in the course of a rapid retreat. They are not often associated with morainic accumulations, but lie upon thinly masked linear and often drumloidal elevations. The relations of the ledge, the bowlders associated with the valley kames at B, and the bowlder fields of the succeeding hills, strongly suggest that we are dealing with one piece of work so far as the Oriskany material is concerned.

But it does not seem probable that the carriage and letting down of the Oriskany bowlders can belong to the general advance to the southern limit of glaciation and the retreat therefrom; for on this supposition they should have reached to Binghamton and beyond. The texture, indeed, is not so firm as that of the Oneidas, but the comparatively abrupt manner in which they terminate renders their connection with a long continued and far southward movement questionable. It is suggested as a matter for farther inquiry, whether the termination of some such vigorous and rapid forward movement as seems indicated by these bowlders, may not be marked by the kames and other valley accumulations between Oxford and Greene, just southward from the last found pieces of the sandstone. This section belongs to a "Collateral belt of moraines" described by Chamberlin, in this region.*

Corniferous Limestones.—This formation overlies the Oriskany sandstone at Oriskany Falls, and has a thickness of at least 50 feet. For three or four miles it is quite freely mixed with other rocks in the hillside drift. Northwest of Hamilton, where the turn of the valley brings the Oriskany drift upon its western wall, Corniferous bowlders are found far exceeding those seen elsewhere. One slab near the valley bottom measures $19 \times 11\frac{1}{2} \times 3$ feet. Farther up, other and more rounded masses were seen, one of which measured $6 \times 6 \times 9$ feet. Near Eaton village also is a tract where limestones exceed all other materials of the bowlder drift. This illustrates a quite general fact in the distribution of the more local drift, that the blocks of a given kind are often found in groups, dependent upon local conditions of exposure, plucking and transport. South

* Term. Mor. Sec. Gl. Exp, 3d Ann. Rep. U. S. G. S., p. 372.

of Hamilton, limestones are rare above the kame and terrace limit, for which 100 feet is an average figure.

The writer has not found a fully satisfactory interpretation for the distribution of the limestones. The case may be stated as follows: from 8 to 12 feet of sandstone are intercalated in the midst of 200 or more feet of limestones at Oriskany Falls. The whole mass was attacked by the glacier. The amount of limestone left on the hills southward bears no comparison to the amount of sandstone. The limestone is practically absent from the hill summits beyond six miles. The Oriskany continues in good force for over 20 miles. That the Lower Helderberg continues far south in the valley train, might be expected, from prolonged erosion in the valley bottom at Oriskany Falls, during the presence of the ice front there, after work upon the higher sandstones had become ineffective. But how shall we get the limestone deposited in kames, with some striations still preserved, at Oxford, 40 miles south, without carrying the fragments of the same terrane to the hills above? We might suppose a valley tongue to account for the kames and the absence from the hills, but the distance is too great, with the slight descent, to admit of this view. Owing to the solubility of the limestones we may believe them less capable of distant carriage by glacial action, the pebbles of the valley being hastened forward by sub-glacial water currents. But we have records of limestone carriage for at least 60 miles.* Professor Shaler notes the disappearance of crystalline limestones within five or six miles.† But here again Emmons records the finding of many bowlders of "Primary" limestone south of Rome,‡ New York, and one two feet in diameter is reported from Clinton, New York. These latter fragments have with little doubt traveled as much as 60 miles.

We may perhaps find relief in the history of the gathering of the materials by the ice. The Corniferous overlaid by the perishable Marcellus shale and breaking up easily owing to its large quota of flints and the solubility of the lime, may have receded along the lines of its ancient outcrop, leaving considerable areas of sandstone exposed. A short and vigorous ice movement might pluck and carry off extensive masses of the sandstone, before action became highly effective upon the limestone ledges in retreat above, or those protected below. We may thus suppose the Oriskany to be well started on its journey before the migration of the limestones was fairly begun.

* Chamberlin and Salisbury, Driftless Area of the Upper Mississippi Valley, 6th Ann. Rep. U. S. G. S., p. 267; also, A. P. Low, Glacial Geology of Labrador and Quebec, Bull. G. S. A., vol. iv. pp. 419–421.

† Bowlder Train from Iron Hill, Bull. Mus. Comp. Zool., vol. xvi, No. 11, p. 206.

‡ Agriculture of N. Y., vol. i, p. 260.

If to any extent the movement of the bowlders was by rotation* in the ice mass, the larger and more equidimensional sandstones would have the advantage in the race. The angularity of many of the sandstone blocks, however, renders rotation for this case doubtful.

To sum up briefly the facts of distribution: We find the Archæan and more northern Paleozoic fragments strewn over the whole district at all altitudes, but diminishing southward in size, and sparse in amount on the highest hills, especially to the southward, where the tops of the ranges are often surprisingly free from transported material.† The Oriskany sandstone drops off from the hilltops after about 25 miles and disappears, so far as observation goes, at 40 miles. The Lower Helderberg and Corniferous limestones appear only for six or eight miles at high levels, but continue far down in the valley drift. As a rule local material far exceeds the imported, at a given point.‡ Exceptions to this rule are due to special local conditions. We may note as factors on which the local distribution and southward extension depend: accessibility of the preglacial ledges for plucking; the bedding and joint planes and power of current, as controlling size and number of fragments plucked; surrounding topography as related to removal; southward extension and limit of the current doing the plucking; lithological character as controlling change of form and reduction of size during carriage; zone of carriage and mode of transport as affecting form, size and manner of deposition. This is doubtless a partial statement, and the several factors will be found in combinations of endless variety.

Whatever may be said of the more northern material, it seems plain that that from the Oriskany Falls region was carried in the basal portions of the ice. The position of the ledges and the combing out of the greater number of large blocks by the hill range, seem to assure this view. A valley tongue, whose top barely reached and caught away the blocks, does not satisfy the case. It could not have grappled the masses with sufficient power. It certainly could not have wrought the very considerable elevation which their present situation demonstrates. Had the bowlders risen to the upper zones of the ice while it was at its greatest thickness, the hilltops should show more of far travelled material. It is to be added that while some of the bowlders are rounded, others in the same groups are notably angular, joint blocks carried from 5 to 12 miles with almost no reduction of angles.

* T. C. Chamberlin, Rock Scorings of the Great Ice Invasions, 7th Ann. Rep. U. S. G. S., pp. 232–233.

† See ref. to Rep. Z., Pa. Surv. already cited; also, J. C. Branner, this Journal, III, vol. xxxii, p. 365.

‡ Cf. R. D. Salisbury, Ann. Rep. Geol. Surv. N. J., 1891, pp. 68–70.

The inquiry has afforded general suggestions as to the amount of glacial reduction of the surface of the district. The northern section seems to have suffered most. At and south of the moraine which runs so nearly coincident with the divide, the hills are often drumlin-like, or at least show much fluting, displaying the "linear" topography to perfection. On the slope which descends to the Mohawk, the ice acted with power. In the southern section, the country was less effectively scored and was planed during a shorter period. The bowlder drift in the best strewn fields is more impressive in its appearance, than its actual cubic contents would justify. The Lower Helderberg shelf at Oriskany Falls, so conspicuously stripped of the superjacent sandstones, would probably much more than receive all the Oriskany bowlders dispersed to the southward, if brought back and corded to the thickness of the ledge from which they were borne. If we say that four times as much sandstone has been crushed and carried down the valleys and to the sea, the amount would still be relatively insignificant. Erosion in certain situations, redistribution within moderate distances, and topographic changes, have been very great. Actual reduction of the general surface toward base level doubtless proceeded rapidly during glacial time, but even then, the process was rapid only in the geological sense, and the result a minute fraction of what has been accomplished since the region became a land surface.

Colgate University, December, 1894.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *On the Determination of high Fusing Points.* — A new method of determining high fusing points has been devised by Victor Meyer in conjunction with Riddle and Lamb, based on the principle of measuring the temperature by means of a small air thermometer made of platinum. At the instant when the substance under examination fuses, the air in this thermometer is expelled by means of a soluble gas, into a graduated tube containing a liquid in which the expelling gas is dissolved. The substance to be examined is placed in a small platinum tube, which is attached to the bulb of the air thermometer, and the whole is immersed in a fused salt having a melting point considerably below that of the substance. The air thermometer consists of a spherical bulb of platinum, about 25^{cc} in its capacity, having two somewhat long capillary tubes of the same metal attached to it, one of which just enters the bulb while the other

reaches to the bottom. At top these tubes are bent at right angles, in opposite directions. In making a determination, the salt constituting the bath, contained in a large platinum crucible, is fused and the bulb of the air thermometer, with the attached substance-tube, is immersed therein; connection being made between one of the capillary tubes and a carbon dioxide apparatus and between the other and the gas measuring burette. To fix the point of fusion, a fine platinum wire is previously immersed in the fused substance, this wire being attached to a weight by means of a cord passing over a pulley. When now the substance is again fused by means of the bath, the wire is released and the weight falls and strikes a bell. The current of carbon dioxide is then started and by its means the air in the air-thermometer is driven into the measuring burette. Knowing the capacity of the thermometer, and the volume of air expelled, the temperature can be calculated. By the new method the author has determined the fusing points of KCl as 800·0°, of KBr as 722·0°, of KI as 684·7°; and of NaCl as 815·4°, of NaBr as 757·7° and of NaI as 661·4°; showing that a rise in the atomic mass of the halogen causes a fall in the melting point. Moreover, he observed for RbI the value 641·5° and for CsI, 621·0°; that for KI being 684·7°. For $CaCl_2$ the fusing point obtained was 806·4°, for $SrCl_2$ 832·0° and for $BaCl_2$, 921·8°. While therefore the melting point falls as the atomic mass rises, in the case of the alkali iodides, the reverse is the case with the chlorides of the alkali-earths. In either case however, the salt of intermediate molecular mass shows an intermediate fusing point. — *Ber. Berl. Chem. Ges.*, xxvii, 3129, November, 1894. G. F. B.

2. *On the Preparation of anhydrous Hydrogen peroxide.*—It has been shown by WOLFFENSTEIN that hydrogen peroxide, hitherto considered as very unstable, is capable of concentration and even of actual distillation under diminished pressure, with but little loss from decomposition. Ascertaining that the loss on concentration either in the air or in vacuo arose from vaporization, the author was led to attempt its distillation. A quantity of the commercial peroxide concentrated until it contained 50 per cent of H_2O_2, was purified by extraction with ether; whereby the quantity of H_2O_2 was raised to 73 per cent. On submitting this to distillation on the water bath at the pressure of 68^{mm} of mercury, two fractions were obtained, the one boiling at 71°–81° and the other at 81°–85°; the former containing 44 per cent H_2O_2 and the latter 90·5 per cent. On fractioning again the latter product, a distillate was obtained at 84°–85° which contained over 99 per cent of H_2O_2 and was practically pure peroxide. It is a colorless syrupy liquid, which scarcely wets the containing vessel and which evaporates in the air. It produces a prickly sensation upon the skin, causing a white spot. Even after distillation with soda it reacts strongly acid. Further experiments have shown that the treatment with ether is not essential; a 3 per cent solution being readily concentrated by repeated fractioning

to give the pure substance boiling at 84°–85°.—*Ber. Berl. Chem. Ges.*, xxvii, 3307, December, 1894. G. F. B.

3. *A supposed New Element in the Nitrogen group.*—A preliminary note has been published by BAYER upon a supposed new element which he has discovered in the residues from the older process for the preparation of alumina from the red bauxite of Var. After removing the vanadium as ammonium vanadate and the chromium as hydrate, the filtered liquid is saturated with hydrogen sulphide, again filtered and the sulphides precipitated by hydrogen chloride. This precipitate is deep brown in color, dries to an earthy mass and burns readily to a bright brown powder, evolving sulphur dioxide. It ignites on treatment with strong nitric acid, forming a dark brown solution, which deposits a small quantity of a yellow precipitate containing molybdic and arsenic acids. This brown liquid is free from tin, antimony and tellurium, but contains traces of vanadium, molybdenum and selenium. These are removed by calcining the recently precipitated sulphides, treating the residue with ammonia and ammonium nitrate and concentration of the solution. Two sets of crystals are obtained, one being ammonium molybdate, the other a less soluble substance in cubic crystals olive-brown in color. By dissolving these latter crystals in hydrogen chloride and treating the solution with hydrogen sulphide a trace of molybdenum is removed. Upon allowing the filtered liquid to evaporate in the air, it becomes at first bluish-violet and contains the new element in a lower state of oxidation; subsequently changing to lemon-yellow. In this condition, the oxide is markedly acid, corresponding probably to R_2O_5. The acid is soluble in water, and on evaporation is deposited in yellow crystals fusing at a red heat to a brownish mass. Ammonia converts it into a crystalline olive-green powder, which dissolves in water and crystallizes out in cubes on cooling. After reduction with hydrogen sulphide in presence of hydrogen chloride, the acid yields a voluminous dark violet-brown precipitate, rapidly becoming crystalline. When treated with ammonium sulphide the yellow solution of the acid becomes dark cherry-red from the formation of a sulphosalt. From this solution acids precipitate a sulphide of the color of iron rust. Silver nitrate gives a green precipitate soluble in nitric acid and in ammonia. Magnesia mixture gives a green precipitate in relatively large crystals. A nitric solution of ammonium molybdate gives a yellow precipitate as in the case of phosphoric acid. The chlorides of the new element appear to be volatile, and are readily soluble in water.—*Bull. Soc. Chim.*, III, xi–xii, 1155, December, 1894.

G. F. B.

4. *A Short History of Chemistry.*—By F. P. Venable, PH.D., 12mo, pp. viii, 163. Boston, 1894 (D. C. Heath & Co.). This little book is based upon a course of lectures which the author has delivered for several years to his classes in the University of North Carolina, in the belief, as he tells us that, "one of the best aids to an intelligent comprehension of the science of chemistry

is the study of the long struggle, the failures and the triumphs of the men who have made this science for us." The first part describes the genesis of chemistry, the second treats of the alchemists, the third considers qualitative chemistry, the fourth has to do with quantitative chemistry, the fifth discusses structural chemistry, and the sixth is devoted to special branches of chemistry. Within so small a compass, it is evident that but a limited treatment of so broad a subject can be given. The book appears to be well written and seems adapted to be of service in those institutions where the history of chemistry forms a part of the prescribed course. G. F. B.

5. *Multiple Resonance.*—Various investigations have been made in the subject of the interference of electrical waves; and apparently the diffraction of these waves has been satisfactorily shown. V. BJERKNES points out, however, that an important difference exists between the phenomena of the interference of light waves and those of electrical waves. In the case of light we observe the phenomena by means of instruments which may be termed indifferent, that is, instruments which do not influence or are not influenced by the source emitting the waves. Whereas in electrical resonance, the resonator is especially sensitive to the various conditions of the electrical oscillation. In general the oscillator is more quickly damped than the resonator. Damped waves do not in general show sharp nodes. Various conditions may arise, which depend upon the circumstances of damping. If the resonator in comparison with the oscillator is strongly damped, the ventral segments and nodal points are relatively well defined. While the resonator is relatively insensitive to a stimulus of its own peculiar rate of oscillation. On the other hand, if the oscillator is strongly damped and the resonator relatively weakly damped, as is the condition in most of Hertz's apparatus, the ventral segments and nodes are not clearly defined, while the resonator is especially sensitive to the excitement of its own peculiar oscillations. In the experiments with a diffraction grating these peculiarities must be considered. What may seem to be spectral dispersion may be only the multiple resonance of the instrument.—*Ann. der Physik und Chemie*, No. I, 1895, pp. 58–63. J. T.

6. *Spectrum analyses of the color of the water in the Blue Grotto, of the Swiss ice holes and of the Yellowstone Springs.*—H. W. VOGEL, twenty years ago, examined with a spectroscope the light in the blue grotto at Capri. The water inside and outside the grotto showed an absorption band between the Frauenhofer lines *b* and E together with a disappearance of the red end of the spectrum up to the line D. During the present year he has had an opportunity to examine the water and the light of the walls of the other grottos (green and red) of the island. He found no trace of the absorption band which he had noticed in the blue grotto in his examination of the walls and water in these colored grottos. The red end of the spectrum, however, was

absorbed. A streak of azure-blue water outside the green grotto showed the absorption bands previously observed. The red grotto showed no trace of red light. The spectroscope showed merely the absorption appearances of ordinary sea water. An examination of the Swiss ice holes by the spectroscope showed an absorption of the red end of the spectrum which gradually diminished toward the yellow. No especial or marked absorption bands were noticed. The Yellowstone Springs showed in a pronounced manner Schönn's aqueous bands in the red and red yellow.—*Ann. der Physik und Chemie*, No. I, 1895, p. 175–177.

J. T.

7. *The minimum temperature of visibility.*—A recent paper by P. L. GRAY describes experiments made upon a strip of platinum with the object of determining the minimum temperature at which it becomes visible in the dark. The author refers to the paper by Draper* as giving the only exact results upon the subject. He shows that Draper's temperature of minimum visibility, corrected by recent determinations of the coefficient of expansion of platinum, becomes 490° C., instead of 525°, and is not very much above his own determination given below. Furthermore Draper's conclusion that *all solid bodies become visible at the same temperature* is fully confirmed by the author's observations with bright and lamp-blacked platinum.

In order to determine the temperature of the platinum strip Gray used a modified form of Joly's meldometer,† consisting essentially of a strip of very thin platinum, about 10^{cm} long, 1^{cm} broad and $\frac{1}{50}^{mm}$ thick, placed in a vertical plane. In regard to its use the author says:

"It can be heated by an electric current, and its linear expansion is indicated by an optical method, by which an alteration in temperature of 1° can easily be noticed. The method of calibration is described in Joly's paper, and in that already mentioned, so that it is unnecessary to do more than briefly refer to it here. Minute fragments of substances of known melting-points are placed on the strip and watched through a microscope, while the temperature is very slowly and cautiously raised until, in any case, melting is seen to take place, when the position of the spot of light which indicates the expansion of the strip is noted. In these experiments the substances used were K_2NO_3(339°), AgCl (451°), KBr (699°), and gold (1041°). From these observations a curve showing the relation between temperature and scale-readings is obtained." . . . .

"*Method of Making the Experiments.*—The first requisite was to get the strip in a perfectly dark enclosure, within which both eyes could be directed towards it without strain. To this end the apparatus was enclosed in a wooden box (blackened within), one end of which was replaced by a black velvet cloth, under which the observer placed his head, and which he could gather round

*On the production of light by heat, Phil. Mag., xxx, 345, 1847.
† Proc. R. Irish Acad., III, ii, 38, 1891–92.

his neck and under his chin so that not a ray of light could penetrate the enclosure. The box was about 48^{cm} long, 30 broad, and 22 high, and ordinarily the eyes, in making an observation, would be about 30^{cm} from the strip. The other end of the box was provided with a hinged shutter, which was lifted immediately after an observation had been made, for the purpose of noting the temperature of the strip.

The strip itself was further protected from draughts, etc., by means of a piece of brass, bent twice at right angles, and resting on the slate block below the strip, as in the calibration experiments. The angular dimensions of the surface of platinum, as seen in any experiment, were therefore:

Apparent length = 3° 49′ approximately;
" width = 1 54 "

so that the apparent area subtended was about 36 times that of the full moon.

The current by which the strip was heated ran through a variable carbon resistance, the handle of which was within convenient reach of the observer as he sat with his head under the black cloth. He could thus alter the temperature of the platinum until it was on the very verge of invisibility, a very small fraction of a turn being then sufficient to produce utter darkness where before the area of faint light had been. A contact-breaker was also within convenient reach, so that the current could be broken or made at pleasure, and the objective reality of the faint luminosity at the limiting-point thus demonstrated. When he was satisfied that the limiting point had been reached the hinged end of the box was opened, a beam of light sent to the mirror connected with the strip, and the deflection, giving the temperature, read on the scale. The possible error in the estimation of the absolute value of the temperature may be taken as certainly not more than 2°. . . .

The general conclusions reached are as follows:—

" (1) That the minimum temperature of visibility is the same for a bright polished metallic surface as for one covered with lampblack, although the intensity of the radiation in the two cases may be different.

This result may at first be, to some, unexpected, but a little consideration will show that it might have been, *à priori*, anticipated. For probably temperature governs the highest wave-length from a radiating body, and wave-length governs visibility, at least after an extremely small intensity of radiation has been passed.

(2) That the visible limit at the red end of the spectrum varies greatly for a normal eye, according to its state of preparation, i. e. according to the intensity of the light in which the observer has been before making the observation. . . .

Speaking generally, we may say that a bright light diminishes the sensitiveness of the eye to radiation of low frequency; that

darkness increases it. Or that, as a rule, the eye is less sensitive in the morning than at night.

(3) That for the less sensitive condition, the minimum temperature of visibility for the surface of a solid is about 470° C., but that this may be much reduced by even a few minutes in a dark room.

(4) That at night, a surface at a temperature of 410° is visible, and that by resting the eyes in complete darkness, this may be reduced to as low as 370° nearly, below which apparently one cannot go, since 10 minutes' rest appears to be almost as efficacious as 3 hours'.

(5) That different people's eyes (of no special or known departure from normality) differ somewhat in their 'minimum temperature of visibility,' but probably not to any great extent, if tested under the same conditions as to preparation, etc. . . .

The loss of distinct *color* at the low temperatures is very striking; the appearance to the author, and to most of the observers, has absolutely nothing of red in it, but is like a white mist—the nearest comparison that can be made.

In the *morning* observations, however, when the strip disappeared at from 460° to 470°, the last appearance was distinctly reddish; and this agrees with one observation noted at night, when after getting the visibility critical-point at about 390° C., the temperature was raised until one could declare for certain that the light looked red: it was then found to be 449°.

Of course, in all the observations, the luminous area was most distinctly seen by somewhat averting the gaze from it; generally it was found best to look in the direction of either far upper corner of the enclosure.

As already mentioned, most of the observers pronounced the appearance at the critical-point to be that of a 'whitish mist;' one, however, thought he saw a slight 'lilac tinge' in it; and 'Case G' declared it to be decidedly yellow, which is interesting, because to him a red mark on white paper (such as a pip on a card belonging to one of the red suits of a pack) appears yellow, by artificial light at night.

In one experiment a plate of glass, $\frac{1}{8}$ inch thick, and in another a layer of water, $\frac{1}{2}$ inch thick, were inserted between the strip and the eye, without making the slightest difference in the phenomena; showing (1) that the point where these substances begin to be more or less opaque to infra-red radiation had not been reached; (2) that the small difference in intensity produced by their insertion had no appreciable effect. This last conclusion is far more strongly borne out by the equality of temperature in the case of the bare metallic and the black surfaces, and indicates that in all the cases it was *wave-length*, and not *intensity*, which was determinative of visibility, so disposing of the possible objection that the difference between 'morning' and 'evening' might be due merely to the state of enlargement of the pupil of the eye, which would naturally be more contracted at the one time

than at the other, thus affecting the total amount of radiation falling on the retina. Also, if such an objection were valid, it would imply that fatigue of the muscles of the iris produced a relatively enormous 'time-lag' in following changes of luminous intensity, which we know does not exist.

There seems, in fact, to be little doubt that the difference is due to the retina itself becoming sensitive to long waves after rest, which were incapable of affecting it when it was in some way fatigued by exposure to the ordinary bright light of day.

The next and obvious step is to find the respective wave-lengths corresponding to the different temperatures. This point, however, and others, cannot be determined without some additions to the present apparatus, and will form the subject of a future paper." —*Proc. Phys. Soc.*, London, xiii, 122.

8. *On the liquefaction of air.* — A note communicated by Professor GEORGE DAVIDSON. The recent remarkable experiments of Professor Dewar in liquefying air, etc., recall the experiments of Perkins in 1822–1826 as detailed in a paper of the Royal Society read June 15, 1826 (p. 541).

Mr. Perkins describes the apparatus which he had devised and operated; and says, "this tube [of steel] I filled with water and subjected it to a pressure of 2,000 atmospheres. After repeating this experiment a great number of times, the average of the result showed that the column of water, 8 inches long, was compressed $\frac{2}{3}$ of an inch, or $\frac{1}{12}$ part of its length." . . . . .

"With the same apparatus I also made experiments on the compression of other fluids. The most remarkable result I obtained was with concentrated acetic acid; which, after compression with a force of 1100 atmospheres, was found to be beautifully crystallized, with the exception of about $\frac{1}{10}$ part of fluid, which, when poured out, was only slightly acid. . . . .

As it might be supposed that even glass was pervious to water by such a force, [500 atmospheres,] a small phial was made air-tight, by fitting into its neck a well-ground glass stopper. It sustained pressure of 500 atmospheres without change and was perfectly dry within, although it remained under that pressure 15 minutes. It was next subjected to a pressure of 800 atmospheres, and when taken out was found to be crushed to atoms.

"In the course of my experiments on the compression of atmospheric air, by the same apparatus that had been used for compressing water, I observed a curious fact, which induced me to extend the experiment; *viz.*, that of the air beginning to disappear at a pressure of 500 atmospheres, evidently by partial liquefaction, which is indicated by the quicksilver not settling down to a level with its surface. At an increased pressure of 600 atmospheres, the quicksilver was suspended about $\frac{1}{8}$ of the volume up the tube or gasometer; at 800 atmospheres, it remained about $\frac{1}{3}$ up the tube; at 1000 atmospheres, $\frac{2}{3}$ up the tube, and small globules of liquid began to form about the top of it; at 1200 atmospheres, the quicksilver remained $\frac{3}{4}$ up the tube, and a beautiful transparent

liquid was seen on the surface of the quicksilver, in quantity about $\frac{1}{20\,000}$ part of the column of air. The gasometer was at another time charged with carburetted hydrogen, and placed in the receiving tube with its mouth immersed in the quicksilver; it was subjected to different pressures, and it began to liquefy at about 40 atmospheres, and at 1200 atmospheres the whole was liquefied.

"These instances of apparent condensation of gaseous fluids were first observed in January, 1822; but for want of chymical knowledge requisite to ascertain the exact nature of the liquids produced, I did not pursue the inquiry further," etc., etc.

9. *On the Value of μ for rapid Electrical Oscillations;* by CHARLES E. ST. JOHN (communicated).—In my paper "On Wave-Lengths of Electricity on Iron Wires," in a recent number of this Journal (vol. xlviii, 311). I gave as a by product of my investigation the value $\mu = 385$. Various estimates have been made for this quantity, but there has been a lack of experimental data. A late paper by Ignaz Klemencic in Wiedemann's Annalen, No. 12, 1894, contains the following values of the permeability in case of oscillations of 100,000 per second:

Soft iron $\mu = 118$
Steel $\mu = 106$ to 115

This value of μ led me to reëxamine my own results, and recalculation shows an arithmetical error, by which the values were multiplied by 4, so that the true approximate value yield by the data is 96, the separate values being $\mu = 107$, $\mu = 97{\cdot}5$, $\mu = 83{\cdot}5$ for the different specimens of iron. These are somewhat lower than the results found by Klemencic, but in my experiments the rate of oscillation was much higher.

In this connection a remark made by Mr. Oliver Heavyside in his Electrical Papers, vol. i, p. 361, is interesting. He says that μ is eminently variable but that $\mu = 100$ is a fair average value. Both Klemencic's results and my own confirm this assumption.

Berlin, Jan. 10, 1895.

10. *National Academy of Sciences on Electrical Measurement.*—In July, 1894, an act of Congress was passed to define and establish the units of electrical measure. By this law, Congress made it the duty of the National Academy of Sciences to prescribe and publish specifications necessary for the practical application of the definitions of certain units of electrical measure adopted in the act. This law (H. R. 6500), approved July 12, 1894, is as follows:—

AN ACT TO DEFINE AND ESTABLISH THE UNITS OF ELECTRICAL MEASURE.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That from and after the passage of this Act the legal units of electrical measure in the United States shall be as follows:

First. The unit of resistance shall be what is known as the international ohm, which is substantially equal to one thousand million units of resistance of the centimeter-gram-second system of electro-magnetic units, and is represented by the resistance offered to an unvarying electric current by a column of mercury at

the temperature of melting ice fourteen and four thousand five hundred and twenty-one ten-thousandths grams in mass. of a constant cross-sectional area, and of the length of one hundred and six and three-tenths centimeters.

Second. The unit of current shall be what is known as the international ampere, which is one-tenth of the unit of current of the centimeter-gram-second system of electro-magnetic units, and is the practical equivalent of the unvarying current, which, when passed through a solution of nitrate of silver in water in accordance with standard specifications, deposits silver at the rate of one thousand one hundred and eighteen millionths of a gram per second.

Third. The unit of electro-motive force shall be what is known as the international volt, which is the electro-motive force that, steadily applied to a conductor whose resistance is one international ohm, will produce a current of an international ampere, and is practically equivalent to one thousand fourteen hundred and thirty-fourths of the electro-motive force between the poles or electrodes of the voltaic cell known as Clark's cell, at a temperature of fifteen degrees centigrade, and prepared in the manner described in the standard specifications.

Fourth. The unit of quantity shall be what is known as the international coulomb, which is the quantity of electricity transferred by a current of one international ampere in one second.

Fifth. The unit of capacity shall be what is known as the international farad, which is the capacity of a condenser charged to a potential of one international volt by one international coulomb of electricity.

Sixth. The unit of work shall be the Joule, which is equal to ten million units of work in the centimeter-gram-second system, and which is practically equivalent to the energy expended in one second by an international ampere in an international ohm.

Seventh. The unit of power shall be the Watt, which is equal to ten million units of power in the centimeter-gram-second system, and which is practically equivalent to the work done at the rate of one Joule per second.

Eighth. The unit of induction shall be the Henry, which is the induction in a circuit when the electro-motive force induced in this circuit is one international volt while the inducing current varies at the rate of one Ampere per second.

Sec. 2. That it shall be the duty of the National Academy of Sciences to prescribe and publish, as soon as possible after the passage of this Act, such specifications of details as shall be necessary for the practical application of the definitions of the ampere and volt hereinbefore given, and such specifications shall be the standard specifications herein mentioned.

To meet this requirement of Congress, it was necessary, in accordance with the constitution of the National Academy of Sciences, to appoint a special committee to consider the subject. This was done as soon as an official copy of the law was received from the State Department. The committee, selected from members of the National Academy, was as follows :—

Prof. H. A. ROWLAND, *Chairman*, Johns Hopkins University, Baltimore.
Gen. H. L. ABBOT, United States Engineers, New York.
Prof. G. F. BARKER, University of Pennsylvania, Philadelphia.
Prof. J. TROWBRIDGE, Harvard University, Cambridge.
Prof. C. S. HASTINGS, Yale University, New Haven.
Dr. C. BARUS, Smithsonian Institution, Washington.
Prof. A. A. MICHELSON, University of Chicago, Chicago.

The committee completed the work assigned to them, and the specifications they prepared meet the requirement of the law, and are also in accord with international agreement.

The report of this committee, approved by all its members, was submitted to the National Academy of Sciences at a special

meeting held in New York, on the 9th of February, 1895, and was then unanimously adopted by the Academy.

At the same session, the National Academy of Sciences voted to prescribe and publish the specifications relating to the ampere and volt, as required by the above law.

To secure the necessary publication of these results, it was also voted, that the President of the Academy send a copy of the specifications to each house of Congress, and to the Secretary of State, with the request to the latter that they be issued by the State Department; and further that the Academy print a suitable number for public distribution. Certified copies have already been transmitted to Congress, and to the State Department, and the official copies to be distributed by the National Academy will soon be issued.

This action of the National Academy of Sciences completes the law of July 12, 1894, and makes the legislation of the United States on the standards for electrical measure in advance of that of any other nation.—O. C. M.

New Haven, Conn., Feb. 20, 1895.

11. *Physics for University Students;* by HENRY S. CARHART. Part I, Mechanics, Sound and Light. 344 pp. Boston, 1894 (Allyn & Bacon).—This brief and concise text-book has been prepared by the author to be used by his students in connection with the formal course of lectures by which they are introduced to the subject of general physics; other teachers similarly situated may well find that it also meets their needs. The subjects are for the most part presented clearly; a sufficient number of suitable illustrations accompany the text. The volume is about equally divided between mechanics, sound and light; the subject of light would seem to have deserved relatively a somewhat greater space than sound.

II. GEOLOGY AND MINERALOGY.

1. *The correlation of the Bohemian and Eifilian divisions of the Devonian.**—As the result of observations made in the neighborhood of Prague and the examination of the original collections of the Bohemian fossils the authors have made a comparison of the faunas of the Barrandian zones F. G. and H. with the faunas of the typical Eifelian Devonian.

They show that the Greifenstein limestone of the Rhine contains a fauna equivalent to the Bohemian fauna of the Mnenian limestone, which is above and distinct from that of the Konjeprus limestone. The latter limestone is shown to be the equivalent of the Hercynian limestone of the Hartz and thus they prove the Greifenstein limestone to belong above in the Middle Devonian as an equivalent of the Eifelian Cultrijugatus beds. They restrict the use of the term Hercynian to the calcareous beds of the lower

* Ueber die stratigraphischen Beziehungen der böhmischen Stufen F. Gs. H. Barrandes zum rheinischen Devon. von E. Kayser in Marburg u. E. Holzapfel in Aachen, Jahrb. d. k. k. geol. Reichsanstalt, 1894, vol. xliv, Heft 3, pp. 479–514.

"*wieder Schiefern*" of the Hartz and formations in other regions bearing the same fauna. This limestone, according to their present opinion, is scarcely older than the *unter-Coblenz* or the highest of the *Siegener Schichten*. The equivalents of the Hercynian, so restricted, are the Konjaprus limestone of Bohemia, the Erbray limestone of France, the Ural limestone of Bjelaja river, Russia, and the Lower Helderberg of America.

The following scheme presents the correlations of the Bohemian zones, through the Hessen Nassau sections, with the standard Eifelian formations:

Eifel.	Hessen Nassau.	Bohemia.
Upper Stringocephalus limestone.	Massen limestone.	H^2
Lower Stringocephalus limestone.	Oderhauser and Haina limestones.	H^1
Calceola beds.	Günterod-limestone.	G^3 G^2
Cultrijuatus beds.	Ballersbach-limestone. Greifenstein-limestone.	Mnenian limestone; G^1 (?)
Lower Devonian.		Konjeprus limestone and F^1

This determination, it will be noticed, restricts the Bohemian formations G and H to the Middle Devonian, and draws the line between the Greifenstein and Mnenian faunas, which are regarded as equivalent to the Cultrijugatus beds, and the typical Hercynian fauna of Lower Devonian age. The paper is an excellent illustration of the accurate correlation to be attained by a critical comparative study of local faunas. H. S. W.

2. *Daimonelix of the Lacustrine Miocene of Nebraska.*—Under the name of Daimonelix, Prof. E. H. Barbour has described in the "University Studies" of the University of Nebraska for 1892 and 1894, large open coils occurring in the Nebraska Miocene; the paper is accompanied by many excellent figures, some of them from photographs. The fossils had been called *Devil's corkscrews* and hence the name which he gives them. The coils stand vertically at different heights in a bed about 100 feet thick, and are ordinarily 6 to 8 feet high, though ranging up to over 12 feet, with the thickness of the stem of the coil $2\frac{1}{2}$ to 8 inches. The basal portion is extended out laterally, with a rising curve, to a length sometimes of 13 feet, and has a varying diameter of 6 to 10 inches. The coils are both right handed and left handed; and sometimes they are double.

They were first thought by Prof. Barbour to be fossil fresh-water sponges; but possibly burrows of Rodents which had become filled with sand,—the bones of a Rodent having been found in the base of one of the coils. In his later paper, of July, 1894, he states, on the ground of new observations, that the interior structure of the coils is coarse cellular; and that the surface is one tangle of ramifying, intertwining tubules, of a diameter

from one sixty-fourth to one-eighth of an inch; some are full a fourth of an inch, but the average is about a thirty-second of an inch." "The tubules grow more densely clustered as we pass inward, and finally, as it were, thicken into a white solid compact wall" which in some cases is nearly an inch thick. The conclusion is thence reached that the coiled fossils were some kind of plant.

Prof. J. A. Allen, of the American Museum of Natural History, judging from the descriptions in the paper of 1892, expressed the opinion in the letter to the writer, that they were probably the burrows of a Rodent, one or more species of Rodent having been described from the Miocene beds.

Prof. W. G. Farlow of Cambridge, in view of the later as well as earlier described facts, writes rejecting the idea as to their being Algæ or of any other order of Cryptogams, and says, in conclusion that "on the whole, in spite of the failure of the microscopic sections to show the characteristic structure of roots, I cannot help believing that the coils were really hollows into which something like roots have grown and been fossilized. It would be of great interest to have a microscopic examination of the matrix in which the coils are imbedded; for it might afford a clew as to the possible nature of the filaments of which the coils are mainly composed."

This conclusion of Prof. Farlow is consistent with that of Prof. Allen, that they are probably the burrows of Rodents, and that the winding form of the burrow was adopted, as the latter suggested, to facilitate ascent and descent. J. D. D.

3. *Report of the geological survey of Ohio, Vol. VII., Economic Geology, Archæology, Botany, Paleontology*, pp. i–xvi, i–290, i–700, Plates I–LVI. A colored geological map of the state, 10 folio maps illustrating the coal fields, several woodcuts in the body of text and 11 charts and maps illustrating Archæology. 1893.—The volume is divided into two parts: Part I—Economic—contains chapters on the geological scale and geological structure of Ohio, the clays of Ohio, their origin, composition and varieties, and the coal fields of Ohio, by Prof. EDWARD ORTON, and one on The clay working industries of Ohio, by EDWARD ORTON, Jr. In the first chapter the state geologist calls attention to the importance of retaining the original boundaries of the Waverly group, the lowest member of which is the Bedford shale of Newberry of the northern part of the state, the name Waverly shale having been applied to the extension of the same formation in the southern part of the state. The Ohio shale, including the Huron, Erie and Cleveland shales of Newbury "fills the entire interval between the Hamilton proper and the Catskill group, and in the judgment of some geologists a wider interval even than that named above."

Part II contains the following chapters: Chapter I, The Archæology of Ohio, an abstract embodying the principal results of explorations and discoveries thus far made, designed for those to

whom the hitherto published literature of the subject is not easily accessible, by GERARD FOWKE; Chapter II, Catalogue of Ohio Plants, by W. A. KELLERMAN and WM. C. WERNER. Besides the list itself (pp. 81–406) this article includes a valuable Bibliography of Ohio Botany from 1815–1893. Chapter III, on Paleontology, contains contributions to the Paleontology of Ohio, by R. P. WHITFIELD; 1. Descriptions of fossils from the Paleozoic rocks of Ohio (reprinted from Am. N. Y. Acad. Science, Vol. V, read Oct. 13, 1890). Plates I–XIII accompany this paper. Chapter IV, Observations upon the so-called Waverly group of Ohio, by C. L. HERRICK, pp. 495–515, Plates XIV–XXIV contain an introduction and brief summary of results already published in the Bulletins of Denison University, the Am. Geologist, and Bulletins of the Am. Geol. Society. The author still holds the view that the Berea grit is the real floor of the Carboniferous series—"not necessarily the base of the Carboniferous, but the most convenient base line for the Waverly," remarking that a study of localities "and collections on which Dr. Newberry's opinion [that the Bedford shale fossils are Carboniferous] was founded has convinced the writer that these species do not occur in the typical Bedford, but in thin flags associated or interbedded, while the typical Bedford, especially in central Ohio, where it reposes directly upon the 'Black shale,' carries a considerable series of fossils forming a decidedly Devonian assemblage."—(p. 507). In a critical case like this, it is unfortunate that so keen an observer as Professor Herrick should describe as "typical Bedford" a formation which confessedly does not contain the typical fossils of the Bedford shale. Chapter V, Fossils of the Clinton group in Ohio and Indiana, by AUG. F. FOERSTE, is apparently a republication of the author's paper on this subject which appeared in the Bulletins of Denison University. It is accompanied by plates XXV–XXXVII*a*. Chapter VI contains The Fossil Fishes of Ohio, by E. W. CLAYPOLE, with a supplement by A. A. WRIGHT, on the ventral armor of Dinichthys. Plates XXXVIII–XLIV accompany this chapter. The final chapter, VII, is entitled, New and little known Lamellebranchiata from the Lower Silurian rocks of Ohio and adjacent states, by E. O. ULRICH. This paper is illustrated by a fine series of plates, XLV–LVI, prepared by the author. H. S. W.

4. *Geological and natural history survey of Minnesota.* 22d Annual Report for the year 1893. pp. 210, 1894.—This Report gives account of the final field work of this survey. The state geologist, Winchell, makes the statement that there remains still to be published the third volume of the Final Report, which is in preparation and several Chapters of which have been already printed, and preliminary copies distributed. The following papers are included:—Summary statement; List of rock samples collected to illustrate the notes of N. H. WINCHELL, 1893; Preliminary report of field work during 1893 in northeastern Minnesota, chiefly relating to the glacial drift, by WARREN UPHAM; Pre-

liminary report of field work during 1893 in northeastern Minnesota, by U. S. GRANT; List of rock samples collected in 1893, by U. S. GRANT; List of rock samples collected in 1893, by A. D. MEEDS; Preliminary report of a reconnoissance in northwestern Minnesota during 1893, by J. E. TODD; Notes on the geology of Itasca county, Minnesota, by G. E. CULVER; Preliminary report of field work done in 1893, by J. E. SPURR; Preliminary report of levelling party, by C. P. BERKEY; Preliminary report of field work during 1893 in northeastern Minnesota, by A. H. ELFTMAN; List of rock samples collected in 1893, by A. H. ELFTMAN; Museum additions: Additions to the library since the report of 1892; The exhibit of the survey at the Columbian Exposition, by N. H. WINCHELL. H. S. W.

5. *Twelfth Report of the State Mineralogist of California* for the two years ending September 15, 1894. J. J. CRAWFORD, State Mineralogist, 541 pp. 8vo, Sacramento, 1894.—This, the second biennial report, contains a discussion of the mineral industries of the State arranged conveniently under subjects, as antimony, borax, gold, etc., with a list of localities by counties under each head. Much space (pp. 70–322) is devoted to gold, since the interest in gold mining has much increased during the past two years. The annual gold product, which for a number of years had remained between twelve and thirteen million dollars, is expected to be maintained now at fifteen to sixteen millions. The Report is thoroughly illustrated with views of mining works, maps, plans, etc.

III. BOTANY.

1. *The Ware Collection of Blaschka Glass Models of Plants and Flowers in the Botanical Museum of Harvard University.*—These specimens, which were referred to in the last number of this Journal, are now arranged with a degree of completeness which renders possible a general consideration of their origin and purpose.

In planning the arrangement of the Botanical Museum, the Director was so fortunate as to secure the advice and cordial coöperation of Mr. Alexander Agassiz. In the preparation of the plans much prominence was given to the subject of a synoptic room, where the types of vegetable structure could be comprehensively displayed somewhat after the fashion of the zoological synoptic room. But it was early seen that dried specimens of flowers would be too perishable and alcoholic specimens too obscure to render useful any attempts in this direction by ordinary means. Drawings and paintings of flowers seemed likewise unsatisfactory. Models alone remained. Examination of the available models in papier machè showed that they would occupy too much space, and be possibly misleading in the qualities of texture and color.

It occurred to the present writer that the Blaschkas, the artists who had constructed the exquisite glass models of marine inver-

tebrata and had distributed them from their studio and laboratories in Dresden to museums throughout the world, might be induced to try their hand at the preparation of models of flowers and leaves. A visit expressly for this purpose was made to Germany in 1886. It was only after much solicitation that the Blaschkas, father and son, were led to undertake the construction of a few specimens. These proved entirely satisfactory. They were so thoroughly promising in every respect that arrangements were made at once for the preparation of about a hundred selected types. The Blaschkas reviewed their botanical studies, always with them a favorite pursuit, and engaged in the new work with interest and uninterrupted success. In the case of the elder Blaschka, the work was really the resumption of an undertaking begun at the instance of Professor Reichenbach in 1866. The models which were then made were sent to the Museum of Natural History at Liège, Belgium, and were consumed in the destructive fire of 1868. Since that date, no glass models of plants had been made by either the elder or the younger Blaschka: their time had been fully occupied with the preparation of models of marine invertebrata.

The new undertaking was of course very costly, but this consideration did not deter Mrs. Elizabeth C. Ware and her daughter Miss Mary L. Ware, of Boston, from authorizing extended contracts with the artists for their entire output of flower-models. The subjects for study were carefully selected with reference to a complete representation of the chief types of structure in the vegetable kingdom, and these subjects were confined, where practicable, to the species found in North, South, and Central America. Up to 1888, the generous patrons of the enterprise had not permitted their names to be known in connection with it, but it was now seen that the magnitude and beauty of the collection justified its designation as a memorial to the late Dr. Charles Eliot Ware.

The last contract with the artists bears date of 1890, and runs to 1900. The Phænogamia now on hand comprise 122 natural orders, 407 genera, and 507 species. These figures indicate sufficiently that the subjects have been chosen with reference to the widest possible range of illustration.

Each plant-model is accompanied by models of structural details, for the most part highly magnified. There are 2160 of these details, making with the large models, more than 2,600 pieces of glass-work. The present rate of production is about one hundred of the larger models and five hundred of the minor ones, each year. When it is remembered that all of this work is based on original botanical study of the species in hand, and is accomplished by two artists who carry on their modelling unaided by any assistants, the rapidity of execution must be acknowledged to be marvelous.

As Mr. Walter Deane has shown by his account of a minute examination of the Blaschka models of our Eastern plants, there

is absolutely no flaw in the workmanship. Every detail is given with perfect accuracy and all are drawn to scale.

The subjects are supplied to the artists in the three following ways,—(1) Plants which can be raised out of doors in the garden near the laboratory and studio are cultivated from seeds and roots sent from this country. (2) Central and South American exotics are freely furnished from the Greenhouses of the Court of Saxony at Pilnitz, one mile from the studio, and (3) the economic plants of the tropics have been studied by Rudolph Blaschka during a recent journey made for that purpose. The sketches for these plants are among the most interesting features of the whole enterprise. They consist of accurate drawings of the whole plant, and of microscopic details throughout, together with full records of impressions as to color. These multifarious sketches are supplemented by alcoholic and dried material prepared for the specific object of supplying all possible information regarding structure.

With the exception of a few specimens where the use of very delicate wire is needed, all the models are constructed of glass or a transparent enamel. In some instances, the color is given to the glass before the model is made; in some cases mineral pigments are added after the completion of the form. In no case has there been observed the slightest change in color of the added pigments or in the character of the surface by exposure to light. It may be assumed, therefore, that these models possess a high degree of permanence under ordinary museum conditions. Since they are absolutely faithful copies of the specimens in hand, and since they undergo no change, they are valuable records of form, color and texture for future comparison.

In the case of American plants which are represented by identical species in the old world, the artists have been urged to employ, as far as practicable, the most typical specimens of the old-world form. This has led to the conviction that in no case yet studied are the old-world species *exactly* like ours. In a few instances, the differences are sufficiently marked to justify the separation into two distinct varieties, and in two cases the differences would be interpreted as specific.

From the foregoing, it will appear that the rapidly increasing collection at Harvard University Museum is of use not only to the public and to the students, but also to the systematist who is engaged in coördinating plant forms with a view to expressing affinities.

Further, it will plainly appear that these models are the best possible illustrations of the economic plants of the tropics, supplementing the alcoholic and dried specimens which are everywhere found.

The artists have already constructed some models to illustrate types of Cryptogamia. They have proceeded cautiously along this path, but their success is regarded by competent authorities to be assured. No specimen is allowed to leave their laboratory

which has not been submitted to thorough examination as regards all possible points of doubt, and, hence, the illustrations of Cryptogamia will doubtless prove generally satisfactory. More than one hundred of these models are now in possession of the University, but they are not at present on exhibition, being withheld until the completion of the proposed series of types. With the exception of a few very large specimens, all of the models of flowering plants are now installed for exhibition. G. L. G.

2. *Monograph of the Mycetozoa;* by ARTHUR LESTER, F.Z.S. London, 1894, 8vo, pp. 224, Pl. 78 and 51 woodcuts.—The present monograph printed by order of the Trustees of the British Museum is the most important descriptive work on Mycetozoa which has appeared since the publication of Rostafinski's monograph on the order in 1875. That work, although written in Polish and therefore inaccessible to most botanists except in the partial translations and extracts given in the writings of Cooke, Schroeter and Berlese, served greatly to stimulate the interest of botanists in both Europe and America in the systematic study of these anomalous growths on the border-line between the animal and vegetable kingdoms. The result was the publication of numerous articles and monographs by the botanists of both continents but until now there has been no satisfactory critical general revision reducing to a solid basis the many scattered facts and descriptions. Mr. Lester's Monograph purports to be only "a descriptive catalogue of the species in the Herbarium of the British Museum" but it is much more than that. It is in fact a general monograph including descriptions of all known species, those of species not represented in the collections of the author and the British Museum being quoted from the original sources often with critical notes.

Mr. Lester's well known studies on the development and cytological peculiarities of Mycetozoa have contributed to give additional value to his more strictly systematic work and prevented his attaching undue weight to the trivial and accidental characters on which systematists are often inclined to depend. In the preparation of his work he has made extensive studies in the field, corresponded with specialists all over the world and examined the types in British and Continental collections. Probably no other botanist has ever had so much or so good material of the kind pass through his hands. In the presentation of his subject the author has shown great clearness and good judgment as well as extensive knowledge and where he differs from other writers he is courteous as well as candid.

The Introduction gives an admirable summary of the life history of the order including some original matter especially relating to the development of Ceratiomyxa. He includes Ceratiomyxa in the subclass Exosporeæ following Rostafinski and De Bary although admitting that the subclass is in some important respects unlike the rest of the order but he does not include the numerous monad-like forms classed by Zopt with Mycetozoa.

On the technical question whether Mycetozoa are plants or animals the author contents himself with the short remark that "the ingestion of bacteria by the swarm-cells appears to strengthen the view that the group is more nearly associated with the lower forms of animal than of vegetable life? The subdivisions of the Exosporeæ here given are essentially those adopted by Rostafinski. The Protodermaceæ disappear since the only supposed representative proves to be a Licea. The total number of genera of the order is given as 43 and the number of species of which descriptions are given is 275. Since a doubt exists as to the genuineness of some of the latter it will be seen that an unusually large proportion of the genera include only a single or, at most, two or three species. Although the number of species admitted by the writer is far short of the number that have been described by different botanists, it seems to us that in his reduction of many of them to synonyms, he is fully justified. One has only to read his excellent descriptions which comprise accounts of the plasmadia as well as the mature structures and his very full notes with regard to type-specimens examined and the variations assumed under different conditions to be convinced that his view with regard to specific limitations is as correct as it is far reaching. His treatment of Stemonitis and Trichia is refreshing after the confused account of those genera to be found in some treatises and even the perplexing genera Physarum and Cribraria lose much of their intrinsic difficulty at his hands.

For American botanists the present Monograph is especially valuable. Besides the specimens of older collectors in various herbaria Mr. Lester has examined abundant recent material from Rex, Macbride, Morgan and the writer, and he has given us at once the most connected and critical account of the species of the United States yet published. He remarks that the species of Mycetozoa have, as a rule, a wide distribution throughout the world and doubts whether unexplored districts are likely to furnish any large number of new species. The book is well printed and very copiously illustrated. The woodcuts of the genera are well adapted for their purpose. The plates of the species are collotype reproductions of water color drawings by Mr. Lester and his daughter and are as a rule very satisfactory. Like all photographs, however, they sometimes fail to give clearly the finer markings. We regret that the original drawings were not reproduced in colors, not that we think the colors themselves necessary in this case but because, the drawings being colored, photography could not be expected to bring out well all the finer points. One sees, in some cases, from the reproduction how much better the original drawing must have been. W. G. F.

IV. Miscellaneous Scientific Intelligence.

1. *The Life of Richard Owen;* by his grandson the Rev. Richard Owen, M.A. with the scientific portion revised by C. Davies Sherborn, also an essay on Owen's position in Anatomical Science by the Right Hon. T. H. Huxley, F.R.S. Portraits and illustrations. In two volumes, pp. 409 and 393. (London, John Murray; New York, D. Appleton & Co.). 1894—This is a remarkably interesting and vivid sketch of the life and experiences of one of the most eminent of English men of science told mainly through extracts of private letters to his mother and sisters and the journals of his wife. Owen's published writings--639 titles given in the bibliographic list at the end of the book—show the scientific side of the man and his immense industry, but these private records exhibit the social side of his life, tell of the men he met, the journeys he took, the modes of his work, the honors showered upon him, and, not least interesting, the many sources from which came the anatomical treasures he described; the Dinornis bones from New Zealand, the Mylodon from South America, Dicynodon skull from South Africa, sent by Prince Alfred, and everything rare and uncanny, as the "adder with two hind legs" from Charles Kingsley, from every part of the earth where Englishmen wandered. We see him dissecting the defunct criminals who perished in Lancaster Jaol, describing the Hunterian collections and lecturing at the College of Surgeons, reading papers at the British Association and in various learned societies, or at the Royal Institution, or to the young princes and princesses at Buckingham palace.

We find him chatting with Carlyle, Tennyson, or Dickens, or Ruskin, on art, music and Shakespeare, serving as an active member of the Commission of Inquiry into the health of towns, which leads him all over the kingdom examining slaughter houses and fish ponds, etc., or discussing with Gladstone or Lord Russell the plans for the British Museum, or dining at the club with Lord Macaulay, Duke of Argyle, Dean Milman, Whewell, or again with Sir R. Inglis, Chev. Bunsen, Mr. Brooke, the Rajah of Sarawah, and others, or traveling up the Nile with the Prince and Princess of Wales, Sir Samuel Baker, the Duke of Sutherland, the Bishop of Bombay, and his Excellency Nubar Pacha, or unbending and singing songs at the jovial meetings of the "Red Lions" of the British Association.

All the story is so directly told that we seem to see the genial, ever busy but always cheerful companion of his many friends as he goes about accomplishing the great work of his life.

The book closes with an account of Owen's position in the history of Anatomical Science, written by Mr. Huxley, who, though often differing with him on scientific theories, speaks with knowledge and appreciation of his great contributions to their favorite science. H. S. W.

2. *The Life and Writings of Rafinesque;* by Richard E. Call. Filson Club Publications, No. 10. Read at the Filson Club meet-

ng, at Louisville, of April 2, 1894. 228 pp., 4to, with portraits and other illustrations. Louisville, Ky., 1895.—The name of Rafinesque, has, in this sumptuous volume and the kindly sketch of Dr. Call, all the generous treatment and honor that the eccentric naturalist could have reasonably desired. The many puzzling problems which Rafinesque left behind him in consequence of his eagerness and keenness of eye in noting distinctions, but hasty work in naming and describing genera and species, thereby duplicating names already accepted, and multiplying names with imperfect descriptions, or with no descriptions at all, have given much labor to those who would do him justice, and led some to question whether the study of any part of his scientific papers is not time lost. Dr. Call gives a lifelike picture of the enthusiastic naturalist and a judicious account of his work; and while admitting that part of the latter is peculiarly bad, rightly claims that what is good should be accepted. The volume closes with a carefully prepared bibliography. This Journal contains some of Rafinesque's earlier papers in its first volume, and an excellent biographic sketch and review of his botanical work by Dr. Gray, in volume xl, p. 221, 1841.

3. *The Mineral Collector.*—With the February number, this periodical has concluded its first volume. It is devoted to "the interests of the collector, student, dealer and miner of mineral specimens" and contains much both in articles and informal notes that is of interest and value to those mentioned and hence deserves their support. It has been through the past year under the editorship of Albert C. Bates and Arthur Chamberlain; and the ensuing year Mr. Chamberlain will take charge alone. The subscription price is one dollar per year (editorial address, 26 John St., New York City).

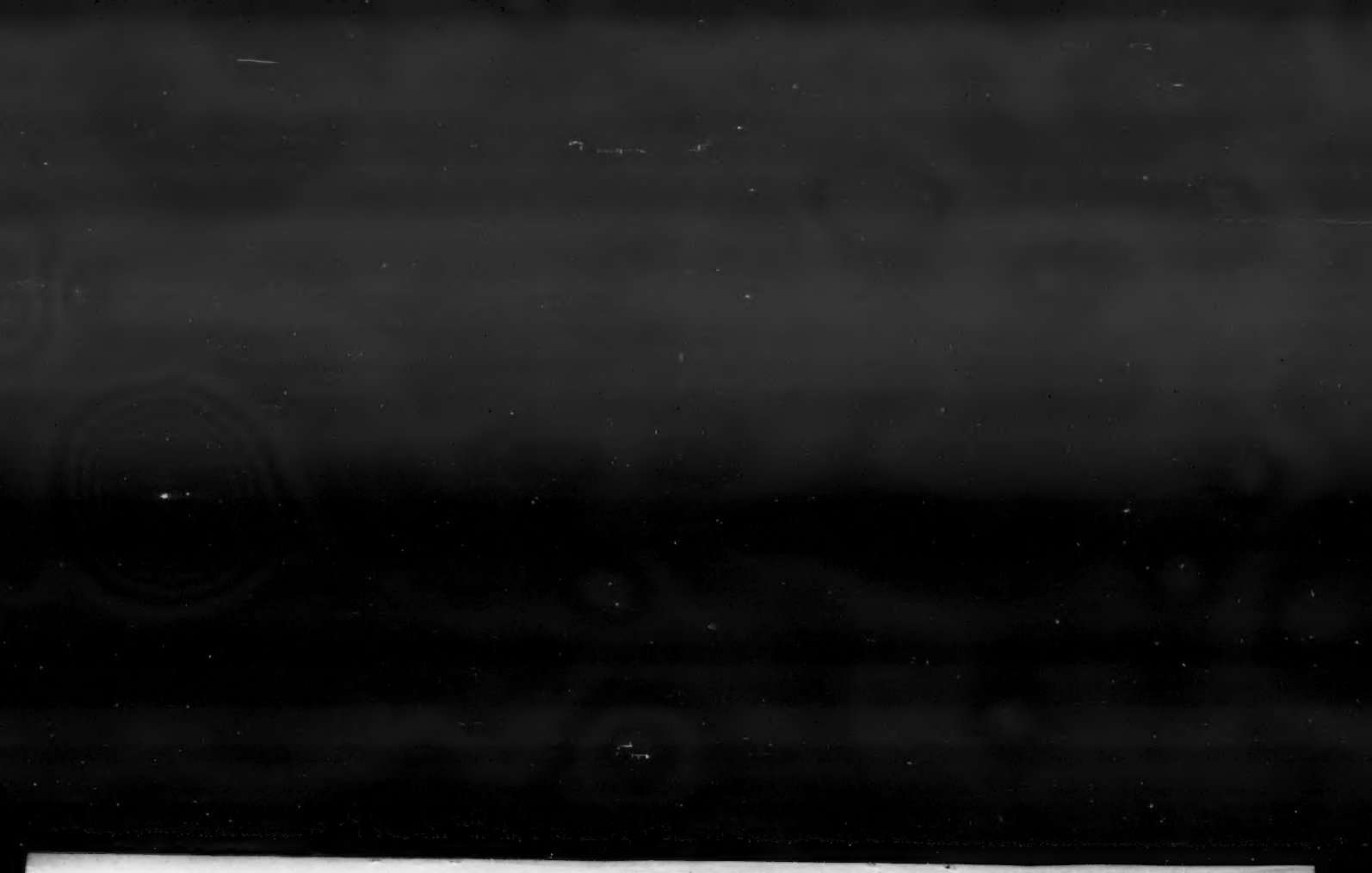
4. *Geological Society of London.*—The Bigsby medal has been presented by the Geological Society of London to Mr. Charles D. Walcott, Director of the U. S. Geological Survey.

5. *Geological Survey of Canada.*—Dr. George M. Dawson has been recently made Director of the Geological Survey of Canada, in place of Dr. A. R. C. Selwyn, who has retired at an advanced age.

OBITUARY.

Professor Arthur Cayley, F.R.S., the eminent mathematician of Cambridge, England, died January 26 in his seventy-fourth year.

Dr. F. Buchanan White, distinguished for his labors in entomology and botany, died at Perth, Scotland, December 3d.

Dr. Murray Thomson, Professor of Experimental Science at Roorkee, India, died January 13th in his sixty-first year.

Dr. Karl von Haushofer, Professor of Mineralogy at Munich, died early in January.